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Operation Heli-STAR - Helicopter Noise Annoyance Near Dekalb Peachtree Airport

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Final Report

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16. Abstract

Operation Heli-STAR (Helicopter Short-Haul Transportation and Aviation Research) was established and operated in Atlanta, Georgia, during the period of the 1996 Centennial Olympic Games. Heli-STAR had three major thrusts: 1) the establishment and operation of a helicopter-based cargo transportation system, 2) the management of low-altitude air traffic in the airspace of an urban area, and 3) the collection and analysis of research and development data associated with items 1 and 2. Heli-STAR was a cooperative industry/government program that included parcel package shippers and couriers in the Atlanta area, the helicopter industry, aviation electronics manufacturers, the Federal Aviation Administration (FAA), the National Aeronautics and Space Administration (NASA), and support contractors.

Several detailed reports have been produced as a result of Operation Heli-STAR. These include 4 reports on acoustic measurements and associated analyses, and reports on the Heli-STAR tracking data including the data processing and retrieval system, the Heli-STAR cargo simulation, and the community response system. In addition, NASA's Advanced General Aviation Transport Experiments (AGATE) program has produced a report describing the Atlanta Communications Experiment (ACE) which produced the avionics and ground equipment using automatic dependent surveillance-broadcast (ADS-B) technology. This latter report is restricted to organizations belonging to NASA's AGATE industry consortium. A complete list of these reports is shown on the following page.

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Operation Heli-STAR Technical Reports

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Volume 7 DOT/FAA/ND-97/15	Operation Heli-STAR - Cargo Simulation System; Ellen Bass, and Chasles Stancil; Georgia Tech Research Institute, Atlanta, Georgia, September 1997
Volume 8 DOT/FAA/ND-97/16	Operation Heli-STAR - Community Involvement; Christine Eberhard and Bobbi Rupp; CommuniQuest, Inc., Manhattan Beach, California; September 1997
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FOREWORD

This is Volume 3 of a 9-volume report documenting the activities and results of Operation Heli-STAR, the Atlanta Short-Haul Transportation System (ASTS). ASTS was a cooperative government/industry program that established a helicopter transportation system to support community of Atlanta during the 1996 Olympic games. Volumes 2 through 5 of this set of reports documents the noise studies that were performed during Operation Heli-STAR. The noise research was performed by Georgia Tech Research Institute (GTRI). GTRI also produced two additional reports documenting Operation Heli-STAR. Volume 6 describes the aircraft position data processing research, and Volume 7 documents a Cargo Simulation System that was used in support of Heli-STAR cargo operations. The research and development elements of Operation Heli-STAR were funded by the Federal Aviation Administration through Science Applications International Corporation (SAIC).

The GTRI manager of the overall ASTS program was Mr. C. Stancil. The Principal Investigator of the noise studies, reported in volumes 2 through 5, was Dr. K. K. Ahuja of GTRI. GTRI personnel responsible for making and analyzing day-to-day noise measurements were Dr. R. Funk and Mr. Jeff Hsu who were assisted by a team of 20 researchers. Ms. Marcie Benne, a graduate student from the School of Psychology lead the effort on the community survey reported in Volume 2. She was assisted by Ms. Mary Lynn Rivamonte, a student in the School of Aerospace Engineering. The authors are particularly grateful for Dr. Mike Heiges of GTRI for providing the helicopter altitudes and flight paths and to Mr. Stephen Williams, also of GTRI, for setting up the microphone locations for noise contour measurements.

The titles of the four volumes reporting noise research are:

Volume 2 - Helicopter Noise Levels Near Dekalb Peachtree Airport

Volume 3 - Helicopter Noise Annoyance Near Dekalb Peachtree Airport

Volume 4 - Helicopter Noise at Heliports

Volume 5 - Effects of Buildings on Helicopter Noise

The titles of the other two volumes authored by GTRI are:

Volume 6 - Aircraft Position Data

Volume 7 - Cargo Simulation System

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EXECUTIVE SUMMARY

Increased helicopter traffic at Dekalb-Peachtree Airport during the 1996 Olympic Games caused an increase in local day-night levels (DNLs). This study examines the relationship between increased noise and the annoyance levels in the surrounding community. Three neighborhoods with a combined total of 353 homes were selected to participate in this study in order to accomplish the following objectives:

- Determine if residents detect increased noise when a helipad is added to a pre-existing general aviation airport.
- Determine if residents are more annoyed because of increased noise when a helipad is added to a pre-existing general aviation airport.
- Test the predictive usefulness of the Schultz curve in an area of high helicopter traffic.
- Compare annoyance resulting from helicopter noise to annoyance resulting from other sources.

Twenty-one sound level meters were used in the neighborhoods to determine DNLs. The homes were then grouped by DNLs prior to the Olympic Games; DNLs ranged from 54 dBA to 63 dBA. Letters were sent to all the residents to introduce the interviewers and ask for cooperation with the survey. Prior to the Olympic Games (July 12-14), under normal air traffic conditions, 70 residents were surveyed on their attitudes towards their neighborhood in general, the noise level in their neighborhood, and their annoyance with specific noise sources. During the period of increased helicopter traffic at the 1996 Olympic Games in Atlanta (July 28 - August

2), the DNLs were calculated again at the same sites as during the Pre-Olympic period, this time ranging from 61 dBA to 72 dBA. Sixty of the same people who were interviewed prior to the Olympic Games were interviewed a second time. Seventy-two additional residents were interviewed. The second survey contained the same questions as prior to the Olympic Games. It tested for change in attitudes with increased noise, as well as further investigated residents' attitudes towards specific noise sources, particularly helicopters.

The survey results were compiled into a database and analyzed using commercially available statistical software. Analyses including chi-square, analysis of variance, and regression analyses (for definitions see Appendix F) were run to produce the following general conclusions:

1. The residents did notice a significant change in the noise environment in their neighborhood during the period of increased helicopter activity. Fifty-eight percent of those surveyed attributed this noise increase to helicopter traffic, 21.1% of those surveyed attributed this noise increase to air traffic, and 11.6% of those surveyed attributed this noise increase to both helicopters and air traffic.

2. The community's annoyance level did not increase with the increased noise levels during the Olympic Games. There was no significant increase in the number of people who replied "yes" when asked "Does the level of noise in your neighborhood bother you?" even though some residents experienced increases in DNL by as much as 10 dBA, with the average increase being 5.52 dBA. Also, there was no significant increase in the number of people highly annoyed by either helicopters or airplanes even though these were the noise sources most often cited for the increase in noise.

3. The survey results were also compared to the Schultz curve. The 1978 Schultz curve is a well-accepted predictor of noise annoyance based upon a comparison between percent highly annoyed and DNL. Because there was no significant difference in annoyance between the pre-Olympic period, and during the Olympic period the results were combined to cover DNLs from 55 dBA to 72 dBA. The DNLs for which less than ten residents were interviewed were not used. The percentage of people highly annoyed with fixed-wing aircraft noise and overall noise correlated better with the Schultz curve than the percentage of people highly annoyed with helicopters. This suggests that DNL may not be the best indicator or metric for annoyance with helicopter noise.

4. A comparison of the average level of annoyance with helicopter and airplane noise showed that the annoyance associated with helicopter noise was significantly greater. The average level of annoyance with helicopter noise both prior to the Olympics and during the Olympics was rated as being just above "slightly annoyed." Helicopter noise had the greatest relationship with overall annoyance level. Helicopter noise bothered 48% of those interviewed prior to the Olympic Games and 50% of those interviewed during the Olympic games. Because a large percentage of residents were annoyed with helicopter noise, changes should be managed with caution.

Further studies need to be conducted on the specific characteristics of helicopter noise to account for the difference in residents' attitudes towards helicopter noise in comparison to other noise sources. Residents expressed higher annoyance with helicopters, but this annoyance rating had a relatively low relationship with DNL. Future research also needs to concentrate on

developing a better metric of annoyance caused by helicopter noise than the current noise metric, DNL.

SECTION 1

1.0 OBJECTIVES

The main objective of the investigation reported here was to study the effects of increased helicopter activity on the noise annoyance of a community near a general aviation airport. The study was carried out during 1996 Olympic Games in Atlanta, Georgia.

This study had four specific objectives:

1. Determine if residents detect increased noise when a helipad is added to a pre-existing general aviation airport.
2. Determine if residents are more annoyed due to increased noise when a helipad is added to a pre-existing general aviation airport.
3. Test the predictive usefulness of the Schultz curve in an area of high helicopter traffic.
4. Compare annoyance with helicopter noise to annoyance with other sources.

SECTION 2

2.0 BACKGROUND

2.1 A Note on the Development of Noise Metrics.

The Environmental Protection Agency (EPA) published the "Levels Document"[1] in 1974 to define criteria for measuring environmental noise and set protective levels for noise under certain conditions. This provided guidelines for research on the effects of transportation noise on surrounding communities. Several federal agencies formed guidelines and regulations after the release of the "Levels Document" and the subsequent EPA Guidelines[2] that were established in 1982. In 1992, The Department of Defense,[3] Department of Housing and Urban Development,[4] Federal Aviation Administration,[5] Federal Highway Administration, and Department of Veterans Affairs[6] developed planning guidelines with consideration to noise levels. This has called for an increased study of noise metrics and annoyance ratings using surveys and lab tests.

This interest in the effect of noise on the community has led to the development of several noise metrics to best describe the effect of noise. The three notable metrics used in studies of the effects of noise on a community are NEF (Noise Exposure Forecast), L_{eq} (Long-Term Equivalent A-Weighted Sound Level), and DNL (Day-Night Average Sound Level). NEF is a number given in dB that measures complex aircraft flyover noise approximating human annoyance responses and gives a 12 dB penalty for the hours between 22:00 and 07:00. L_{eq} is based on the average of the A-weighted sound levels over a period of time. This time period (as used in studies of the effects of noise on a community) has generally been a complete, average traffic day, though L_{eq} can also be used just during the peak traffic hours to assess the noise level

during that period. The most commonly used noise metric, DNL, is a version of L_{eq} that covers twenty-four hours with a 10 dB penalty for nighttime noise between 22:00 and 07:00. This penalty adjusts for increased annoyance during sleeping hours. These measurements are used in connection with social surveys to develop predictions on how transportation noise will affect a community.[7,8,9]

2.2 Noise Surveys Done in the Past

The problems caused by noise can be divided into many categories including health problems, activity interference, speech interference, sleep disturbance, annoyance, and environmental degradation. These categories are also interrelated in that disturbance of daily activities and communication generally leads to a higher annoyance level.[10] Standard surveys on the effect of noise on communities by others have included questions on the general background of the participant (length of time in area, age, etc.), general questions about the neighborhood, rating scales for noise annoyance, and specific questions about the sources of noise that are believed to cause annoyance. Fields[11] suggests that future surveys work toward becoming more consistent with each other so that results can more easily be compared. The people surveyed in the majority of noise annoyance studies have generally been in the vicinity of an airport with varying degrees of aircraft traffic. Surveys have been conducted in both large city and smaller residential communities. Questions on the participant's background and his/her attitude toward the target noise source as well as other noise sources provide a measure of whether the annoyance is caused more by the sound level or by non-acoustical factors. Taylor[12] noted the

effects of a person's age, gender, education, length of residence, hours spent outside, children, attitude toward aircraft, concern about accidents, and whether they keep their windows open or closed. This study found that the non-acoustical factors had a greater impact on annoyance than did the acoustical factors.

2.3 Schultz Curve for Predictions of Noise Annoyance

Theodore Schultz developed the so-called Schultz curve in 1978[13] by comparing the results of more than 16 surveys and using the results of 11 of them to form the curve (See Table 2.1). These surveys were usually conducted in large cities and included four street noise surveys, one railroad survey, and six aircraft surveys. The surveys he selected to compare had to meet five criteria: (1) The survey had to include at least one question item that asked directly about long-term annoyance, this could not be inferred from questions about activity interference, etc.; (2) it had to be a survey on a transportation noise source; (3) acoustic measurements had to have been taken, either using DNL or a method that could accurately be converted to a DNL measurement; (4) the number of people surveyed had to be large enough to insure some degree of accuracy; and (5) there had to be an annoyance rating scale that could be used to determine "percent highly annoyed" in a way that it was comparable to the other studies. The Schultz Curve is often used as a reference point to predict noise annoyance due to transportation systems and to develop new surveying techniques.

In creating his curve, Schultz developed the concept of "percent highly annoyed" to standardize the different survey scales so that they could be compared. In general, the "percent highly annoyed" constitutes the top 27-29% of the rating scale used when a participant expresses

their annoyance level on a numbered rating scale, usually either a 7 or 11 point scale. For nominal rating scales, such as "not at all annoyed" to "extremely annoyed" Schultz used the

Table 2.1 Surveys used to develop the Schultz Curve

Subject	Researcher	Date	
French Aircraft	Alexandre	1970	11 Surveys grouped by Schultz in 1978 To form the Schultz Curve
Second Heathrow Airport	MIL Research	1971	
First Heathrow Airport	McKennell	1963	
London Traffic	Langdom	1976	
Munich Aircraft	Rohrman *et al.*	1974	
Paris Street	Aubree *et al.*	1971	
French Rail	Aubree	1975	
Swedish Aircraft	Rylander *et al.*	1972	
Swiss Road	Grandjean *et al.*	1973	
Swiss Aircraft	Grandjean *et al.*	1973	
USA 24 Site	Fidell	1978	
Los Angeles Airport	Fidell and Jones	1975	5 Other Surveys looked at By Schultz but not Used in Schultz Curve
French Expressway	Lamure	1976	
Swedish Road	Rylander *et al.*	1976	
Tracor Large City Aircraft	Patterson and Conner	1973	
Tracor Small City Aircraft	Conner and Patterson	1972	
Vienna Street Traffic	Bruckmayer and Lang	1967	

* Details of these publications can be found in "Synthesis of Social Surveys and Noise Annoyance." by Schultz, 1978.[13]

categories he felt in his best judgment represented the "percent highly annoyed." For instance, on a five point scale including "not at all annoyed", "slightly annoyed", "moderately annoyed", "very much annoyed", and "extremely annoyed," it appears he counted the top two categories as "percent highly annoyed." Schultz plotted the "percent highly annoyed" versus the DNLs in that area to develop his curve to predict noise annoyance.[13,14]

2.4 Impact of Noise from the Road Traffic and Railroads

Many studies have been conducted to determine the effect of transportation noise on the communities in the vicinity of airports since the development of the Schultz Curve (See Table 2.1). A study by the USAF and Finegold validated the Schultz curve as a reasonable predictor of noise annoyance.[15] This is seen in Figure 2.1 taken from Finegold's study. Several of the studies deal particularly with aircraft noise and are conducted around both small and large airports. Some of these studies suggest that the noise from aircraft may be more annoying than the noise from other transportation types such as road traffic and railroads, as Fidell and Osada found in a two separate studies in 1991.[16,17]

One reason for this finding may be that aircraft flyover noise is able to enter the home through the roof as well as two or more sides of the building, where as street traffic noise predominantly enters the home through only one or two sides of the building.

2.5 Civil Aircraft Versus Military Aircraft

A study conducted by Garcia and Faus[8] of the annoyance levels around six Spanish airports found a significant difference between the annoyance caused by civil aircraft and military aircraft. Two of the six airports in this survey had both civil and military air traffic and were found to compare favorably with the other studies when the effect of the military aircraft was omitted. The greater annoyance by military aircraft can be explained in two ways. First is the type of flights, military aircraft tend to fly lower, have different sound levels and spectral frequencies, and irregularly distributed flights. A second cause could be people's attitude towards the military for emotional or political reasons.

2.6 Non-acoustical Factors

The effects of non-acoustical factors is noted in many of the surveys.[8,12,13,18,19] A study by Ahrlin[20] of the effects of air, road, and train traffic showed that the loudness of a sound and its disturbance of activities did not necessarily reflect annoyance. The study showed that even though the effects of train noise on conversation and rest were fairly high, the percentage "very annoyed" was relatively low. At equivalent dB levels, noise of aircraft was found to cause a much higher annoyance level than that of the trains. In a study by Fields and Powell[19] on the noise annoyance associated with helicopters, they found a correlation between questions involving other aspects of helicopters and the participant's annoyance level. For instance "fear that a helicopter might crash nearby" brought with it an increase in annoyance as did the cases where participants felt that pilots and/or authorities could do something to reduce the noise. On the other hand, people who felt helicopter flights were important were less likely to be annoyed by the noise level. Other surveys found that a masking effect was sometimes produced when there were other high amplitude noise sources such as traffic. Schultz[13] noted that a subject's attitude towards his neighborhood or the source of the noise affects the degree of annoyance as much or even more than the level of sound.

2.7 Helicopter Noise Versus Fixed-Wing Aircraft Noise

In addition to the question of whether to judge aircraft noise differently from street traffic and rail noise, there is also the question of whether to judge helicopter noise differently from that of other air traffic noise. This has been the object of several studies conducted in different

ways with a variety of results. Schomer[21] conducted one survey around the Decatur, Illinois Airport, a general aviation airport with surrounding DNLs ranging from 44-66 dB. This survey found that airplane noise annoyance compared favorably with the Schultz curve but that helicopter noise annoyance did not (Figure 2.2). Schomer also studied community attitudinal surveys and reviews of noise complaints from the U. S. Army to assess the effect of helicopter noise on the population. He looked into the idea that helicopter "impulsiveness" increased annoyance and found that outside of a building it had little or no effect at all. Inside the home, helicopter noise had caused annoyance levels comparable to the annoyance levels caused by non-impulsive noise at 0 to 10 dB higher. He attributed this effect to not only the impulsiveness of the noise but also to perception of induced rattles and vibrations in the home[22]. He also supports the notion that C-weighting is a better measure of annoyance than A-weighting when dealing with helicopter noise[23]. Helicopter noise includes the low frequencies that induce rattles and vibrations. Schomer summarizes that while laboratory studies show helicopters to be no more annoying than fixed wing aircraft, field studies show that they are between 0 and 6 dB more annoying than other sound sources, which he attributes to the lower frequencies that cause vibrations[22]. Gjestland[24] used a lab environment to test the levels of annoyance given to helicopters and jets at the same DNL. Participants listened to taped recordings of helicopters and jets both during take off and landing played at the same levels and were asked which was more annoying. In general, the helicopters were actually judged as less annoying than the jets. However the annoyance due to helicopters seemed to be type specific. The Super Puma AS322L was judged to be less annoying than the reference, whereas the Bell 205 was judged to be more annoying. Another field study conducted by Fields and Powell[19] involved multiple interviews of

330 respondents in an area where the helicopter traffic was controlled without the knowledge of the participants or the interviewers. They conducted an initial interview face to face which was followed by 22 interviews over the phone, 17 of which were on days when the type, number and altitude of flights was controlled. This survey also found a difference in annoyance with helicopter type, with a higher annoyance level associated with the more impulsive UH-1H ("Huey") as compared to the UH-60A ("Blackhawk"). Annoyance also increased with both number of flights and noise level.

SECTION 3

3.0 SURVEY STRATEGY

3.1 Test Site for the Present Study

The noise survey reported here was carried out in the neighborhoods of Dekalb-Peachtree Airport. Dekalb-Peachtree Airport is a designated general aviation reliever airport located 8 miles northeast of downtown Atlanta in Dekalb County, Georgia. The aircraft activity includes business jets, general aviation single and twin engine aircraft, and helicopters. The airport facilities include 4 runways, a helipad, 15 corporate hangers, and 9 flight schools. Pilots were instructed to take-off to the north and fly over the MARTA tracks as a noise abatement procedure. Adherence to this procedure varied. Further details on air traffic composition are outlined in Georgia Tech Research Institute (GTRI) project report A5146-110[25], Volume 1.

Homes from the Clairmont, Hardee, and Keswick neighborhoods were selected by their proximity to the Dekalb-Peachtree Airport to participate in the survey (Figure 3.1). In addition to being exposed to aircraft and helicopter noise, the participants in the Hardee and Clairmont neighborhoods were exposed to traffic noise from Clairmont Road, a four lane street of moderate to heavy traffic. These neighborhoods were also exposed to noise from both the railroad line and the city's commuter train line, Metro Atlanta Rapid Transit Authority (MARTA) (Figure 3.1). The three neighborhoods encompassed 353 homes. DNL measurements reported in reference 37 were taken at 14 locations in the Clairmont neighborhood, 5 locations in the Hardee neighborhood, and 2 locations in the Keswick neighborhood.

3.2 Noise Levels in the Neighborhoods Surveyed

Noise measurements were conducted by the acoustics group of the GTRI Aerospace Laboratory. Explicit details on sound meter equipment, measurement procedure and the calculation of day-night levels are also outlined in GTRI project report A5146-110[25], Volume 1. Noise levels reported by GTRI were rounded to two-digit categories for analysis.

Noise was measured prior to the Olympic Games on the dates June 10 through 13, June 17 through 20 and June 24 through 26. These days were considered to have typical general aviation traffic. During the Pre-Olympic period, the DNLs in the Keswick area were the lowest at 54 and 56 dBA, followed by the Clairmont neighborhood which had levels ranging from 55 to 59 dBA, while the Hardee neighborhood had the highest levels ranging from 60 to 63 dBA (Figures 3.2, 3.3).

Noise was measured during the Olympic Games July 22 through 26, 1996. The Olympic Games ran between July 19, 1996 and August 4, 1996 - these days were considered atypical air traffic days. The number of audible occurrences of helicopters, light airplanes, turbo airplanes, jets, trains, cars and trucks within the vicinity of each sound level meter location was also recorded during this period (Appendix A). During the Olympic Games, the DNLs increased to a range of 61 through 72 dBA (See Figures 3.4 and 3.5).

3.3 Selection of Survey Participants

The participants were divided up by the location of their home with respect to the sound level meter locations where data had been obtained, placing participants in the group that had the

closest sound level meter to their home. Locations with equivalent DNL readings were then grouped together. More homes were exposed to DNLs at the lower end of the range. For example, 80 homes were exposed to a pre-Olympic DNL of 55 dBA, while only 10 homes were exposed to a pre-Olympic DNL of 60 dBA. In order to collect impressions from residents at each DNL range, the number of homes surveyed per DNL grouping was proportional to the number of participants in that group, with more surveys being given in the larger groups.

Prior to the survey, a letter shown in Appendix B was delivered to all 353 homes within the target groups . This letter introduced the interviewers and asked residents to comply with the forthcoming survey. During the Pre-Olympic phase, 70 households were surveyed between July 12 and 14, 1996 and designated as group A-Pre-Olympics. The second round of interviews took place during the Olympic period, July 28 to August 2, 1996. Sixty households from group A were interviewed a second time. 72 new households were interviewed to form group B-During. The actual, personal interviews were conducted by two trained researchers. They independently knocked on the doors of homes and asked residents to participate in the survey. Interviews were conducted weekdays, weekends, during days and evenings. Each interview lasted approximately five minutes. Of the 142 residents surveyed, 49% were male and 51% were female, all were over 18 years old.

3.4 Interview Questions

The participants were asked 15 questions developed with reference to Schomer's[21] study in 1983 (See Appendix C). The participants were asked to consider activity in their neighborhood in the past week when responding to the questions. Questions one through three

did not mention noise. These questions allowed the participants to reflect upon their neighborhood without noise considerations. Following the three open-ended questions, noise was mentioned in questions 4 through 13. Questions 14 and 15 were demographic questions. After this questionnaire had been used in the Pre-Olympic period, it became apparent that some changes would benefit the survey. For interviews during the Olympic period, three modifications were made to the questionnaire (Appendix D). These changes, which were considered minor, were:

- Question number six, asking what days and times people generally heard noise in their area, was eliminated because people had a difficult time understanding the query and generating an answer.
- Question number 11.5 was added. It investigated the visibility of noise sources.
- At the very end, question number 16 was added about the blimps in the area for the Olympic Games.

The survey elicited a variety of answer types: open-ended, rating scales and yes/no responses. The answers were coded and were entered in the database. These codes appear on the questionnaire and an accompanying code list (Appendix E).

3.5 Pre-Olympic Versus During-Olympic Surveys

The experimental design entailed a Pre-Olympic versus During-Olympic comparison. Therefore, one group, A, was interviewed before the Olympic Games. These same people would

be ideal for interviews during the Olympic Games, as long as their answers were not primed by the first survey. Because this experiment required participants to be interviewed prior to the expected increase in noise, it was possible that prior exposure to the interview questions might confound participants' answers to the same questions during the Olympic Games. In order to ensure that such priming was not a confound, a second group, B, was interviewed during the Olympic Games only. As shown in Table 3.1, the term Group A-Pre refers to Group A surveyed during the Pre-Olympic period. The same Group surveyed during the During-Olympic period is referred to as the Group A-During. Likewise, Group B is referred to as Group B-During.

Table 3.1. Group Assignments for Surveying.

Pre-Olympic Period	During-Olympic Period
Group A-Pre (70 residents)	Group A-During (60 residents)
142 residents Total	Group B-During (72 residents)

This had two advantages. First, it allowed Group B to act as a control group to which Group A could be tested for priming effects of the first survey. If members of group A-During had significantly greater annoyance levels than Group B-During, they most likely were affected by the initial interview and their During-Olympic data should not be used. Thus, the second advantage of Group B was that if the Pre-interview was a confound for Group A, Group B-During could be compared against Group A-Pre.

3.6 Analysis of the Survey Data

The results that follow include analyses of regression, chi-square analyses and analyses of variance. Each of these statistical procedures is defined in Appendix F. In addition, all hypotheses tested in this study are outlined in detail in the appendices G through R. Three forms of the dependent measures were used, each describing the extent of annoyance. The first was simply the form in which it was collected: as an individual's rating on a 5 point scale. The second was in the form of a population frequency, or proportion of the population that expressed annoyance. The third was our entire community's average level of annoyance on a rating scale. The average value of a rating scale is often used for analyzing questionnaires, but it requires the assumption that the intervals on the scale are equal.

Comparisons were made between the Groups A-During and B-During on the DuringOlympic data for the reasons described in the prior section. Effects of interview priming were not apparent because the responses given by A-during were no higher than those given by B-during. This means there is no suggestion that respondents had artificially high levels of annoyance in the four categories checked by analyses: overall noise, fixed-wing aircraft noise, car noise or helicopter noise. (Appendix G). Restated, this means that the residents who were interviewed a second time did not have inflated levels of annoyance just because they thought that the investigators were interested in annoyance. This allowed further analyses to include Group A-During.

In summary, it is reasonable to compare A-Pre to A-During. It is also reasonable to combine the data of Group A-During and Group B-During because the data are not significantly different. They can be considered as samples of the same population.

The results of this study focus on annoyance with helicopter, fixed-wing aircraft and overall neighborhood noise. Other sources of noise in the neighborhoods (cars, trucks, trains, MARTA) are not discussed because very few people claimed to notice them or be bothered by them. In addition, the non-acoustical factors we examined appeared to have no differentiating effects on annoyance (age, length of residence, siding type and air conditioner use).

SECTION 4

4.0 RESULTS

These results address four questions. First, did the residents in the vicinity of a general aviation airport notice an increase in noise levels during the Olympic games? Second, did the residents' annoyance levels increase during the Olympic Games? Third, does the Schultz Curve have predictive-usefulness when planning for high helicopter traffic? Fourth, how does the annoyance caused by helicopter traffic compare with annoyance caused by other sources? The conclusions from these analyses are discussed in the following sections.

4.1 Did residents notice the noise level increase during the Olympic Games?

The results clearly indicate more residents of the three neighborhoods recognized the louder acoustical environment during the Olympic Games as compared to before the Olympic Games.

Question number six asked, "Have you noticed any changes in the noise level in your neighborhood?" Significantly more residents answered "yes" to this question during the Olympic Games than had answered "yes" to the same question prior to the Olympic Games (Table 4.1; Appendix H).

The residents who responded yes to the previous question were then asked an open-ended question; "What was the change in noise?" The first response each resident gave was recorded. Of the residents who noticed the change during the Olympic Games, 58.0% of them attributed the change in noise to an increase in helicopter traffic, 21.1% attributed the change to increased air traffic, and 11.6% attributed the change to increases of both fixed-wing aircraft and

Table 4.1 Responses to the question:

"Have you noticed any changes in the noise level in your neighborhood?"

	Pre-Olympic Games Group A	During-Olympic Games Group B	Total Residents
Yes, noticed change.	19	48	67
No, didn't notice.	51	24	75
Total Residents	70	72	142 residents

helicopter traffic. Because the residents perceived an increased noise level, it was expected they would have higher annoyance levels, but the following paragraphs illustrate that was not the case.

4.2 Did residents' annoyance levels increase during the Olympic Games?

Annoyance levels did not rise with the increased noise level during the Olympic Games.

The perception residents had of a noise level increase was completely substantiated by the noise measurements taken by GTRI.[37] The GTRI noise measurements prior to the Olympic Games and during the Olympic Games indicate a mean increase of 5.52 dBA across the 132 households interviewed during the Olympic Games. The change in the DNL ranged from 0 (no change) to 10 dBA. Of those participating, most households experienced an increase of 7 dBA as shown in Table 4.2.

Because these residents were subjected to increases in noise, several analyses were conducted to detect changes in annoyance level. The first analysis was conducted on the

responses the residents had to questions regarding noise "overall," which should correspond to DNL, because DNL is a measure of all environmental noise. The hypothesis for this first

Table 4.2 The percentage of residents exposed to each increase in DNL.

Extent of change in DNL	0 dBA	3 dBA	4 dBA	5 dBA	6 dBA	7 dBA	8 dBA	10 dBA
% of participating households exposed to that change	7.6	4.5	7.6	28.0	10.6	34.1	5.3	2.3

analysis was: if DNL increased, then the number of residents annoyed should have increased. Question number five on the survey asked, "Does the level of noise in the neighborhood bother you?" (See Appendices B and C). It was expected that the number of "yes" responses to this question would be greater during the Olympic Games than prior to the Olympic Games. Instead, Table 4.3 illustrates that no significant increase in the number of people annoyed with the general neighborhood noise level was detected (Appendix I).

Table 4.3 Responses to the question:
"Does the level of noise in the neighborhood bother you?"

	Pre-Olympic Games Group A	During-Olympic Games Group B	Total Residents
Yes, am annoyed	25	27	52
No, am not annoyed	45	45	90
Total residents	70	72	142 residents

The table above illustrates that the number of residents annoyed with the noise level overall did not increase. Still, it was expected that people's annoyance with fixed wing aircraft noise would increase, because residents had attributed the increase in the noise level to increased aircraft activity. However, among those who noticed fixed-wing aircraft noise, the average level of annoyance on a 0 to 4 (5 point) scale (from not at all annoyed to extremely annoyed) did not increase. The average level of annoyance with fixed-wing aircraft remained the same, even during the increased DNLs; (See Appendix J). The community was slightly annoyed with the noise from fixed-wing aircraft both prior to the Olympic Games and remained so during the Olympic Games.

At the same time, among those who noticed helicopter noise, the average level of annoyance with helicopters did not increase. On the 0-4 scale, the average level of annoyance was the same during the Olympics as it had been prior to the Olympics (Appendix K). The residents were more than slightly annoyed with the helicopters both prior to the Olympic Games and during the Olympic Games.

The three analyses thus far did not detect increased annoyance with overall noise, with fixed-wing aircraft noise or with helicopter noise during the Olympics. During the Olympics, the residents were subjected to seven different DNLs depending upon the location of their homes. These DNLs were: 61, 62, 63, 64, 66, 70 and 72 dBA, respectively. Therefore, a hypothesis was tested that the seven categories of DNL recorded during the Olympics might correspond to residents with different annoyance levels. It seemed reasonable to expect the higher DNLs to relate to residents with higher annoyance levels, but no significant difference was found for

annoyance with overall noise during the Olympic Games. The residents' annoyance levels did not differ between the DNLs of 61, 62, 63, 64, 66, 70 and 72. (See Appendix L).

Because the community was not more annoyed due to DNL directly, it was hypothesized that those who experienced large changes in DNL might be more annoyed than those who experienced small changes in DNL. For example, if a household was within a 54 DNL environment prior to the Olympic Games and a 64 DNL during the Olympic Games, the increase of 10 dBA might result in greater annoyance than an increase of 1 dBA from 63 to 64 DNL. The households fell into eight categories of "change in DNL," 0, 3, 4, 5, 6, 7, 8 and 10 dBA. No significant difference on average level of annoyance with overall noise was detected between the eight categories of "change in DNL," regardless of whether the change was 0 or 10 DNL (Table 4.4; Appendix M). Furthermore, our analysis also failed to detect a difference between the average levels of annoyance with helicopter noise at each change in DNL (See Appendix M).

Table 4.4 Average annoyance level with overall noise within each increase in DNL.

Extent of change in DNL	0 dBA	3 dBA	4 dBA	5 dBA	6 dBA	7 dBA	8 dBA	10 dBA
Average level of annoyance*	1.10	2.17	1.20	0.94	0.64	1.07	0.714	0.00

*(0-4 scale; not at all to extremely annoyed)

The collection of analyses just described failed to detect a relationship between DNL and annoyance with overall neighborhood noise or annoyance with aircraft noise. This survey includes 142 households out of a possible 353 in the target area. While this sample of 40% is reasonable, it is possible that the analyses of variance conducted across DNL in this section

distributed the data points over so many categories that the power to detect an effect was reduced. It is also possible that the residents' annoyance levels did not increase because they knew the noise was temporary.

4.3 Did the Schultz curve predict annoyance due to helicopter noise?

A predictor of community annoyance already exists in the form of Schultz curve. The Schultz curve was described in the introduction of this report. It is possible that the curve is not sufficient for an area with a disproportionate number of helicopter occurrences. If the Schultz curve is to be useful when managing helicopter noise,

- it should successfully predict the increase in the percentage highly annoyed with each unit increase in DNL,
- or it should predict the percentage of the population annoyed at each DNL.

The following analyses suggest the Schultz curve is somewhat questionable as a predictor of the effects of helicopter noise. The following analyses attempt to compare the observations of this study with the Schultz curve. The first decision made was whether to compare the Schultz curve to actual data or to the best-fitting regression curves on actual data. Two comparisons were made, the first is merely descriptive with the actual data of this study and the second is inferential with the best-fitting regression curves through the actual data.

The present data were reorganized specifically for this analysis in three respects. First, since no difference was detected between Pre-period annoyance and During-period annoyance with overall noise, helicopter noise, or airplane noise, it was possible to combine the data from pre-Olympics and during-Olympics to relate to DNL. Second, Schultz[13] plotted the distribution of DNLs against the percentage of people highly annoyed with the noise source. Schultz's

category of "highly annoyed" was a variable including the most annoyed respondents on each of the surveys he reviewed. Therefore, in the present study, the variables "very much annoyed" and "extremely annoyed" were combined to match Schultz's category of "highly annoyed." Third, the percentage of highly annoyed respondents for overall noise, helicopter noise, and airplane noise were plotted against the Schultz curve in Figures 4.1 and 4.2. Figure 4.1 shows the actual observed data and Figure 4.2 is a graph with the best-fitting curves of the observed data (the same regression was applied to the observed data as had been applied to the Schultz data). GTRI's pre-Olympic and during Olympic measurements indicated that neighborhoods experienced a range of DNLs from 55 to 72 dBA. Because the dependent variable, percentage highly annoyed, is based on a percentage of the population, small populations result in extreme percentages of highly annoyed residents. For example, a population of 2 results in 0%, 50% or 100% highly annoyed. To avoid this problem, only DNLs which included 10 or more households were included in this comparison to the Schultz curve. The DNLs in this study that did have 10 or more participants included: 56, 61, 62, 63, and 64 dBA.

The Schultz curve would be useful in predicting the impact of helicopter noise on the public if it successfully predicted the increase in percentage annoyed with each increase in DNL. To analyze the utility of the Schultz curve in this sense, it was compared with the observations made in this study (Figure 4.1). The graph of the Schultz curve illustrates a prediction with very little change in the percentage of people highly annoyed between the DNLs of 56 and 64. In other words, the Schultz curve predicts a range of 4.57% to 12.11% highly annoyed, a difference of less than 8% over eight DNLs. This predicts a steady increase of about 1% of the population with each increase of 1 dBA. To the contrary, the observed percentage of annoyed in this study

did not increase steadily with DNL, nor was the range limited to 8% points. The percentage highly annoyed with overall noise in this study seemed to increase and decrease non-systematically between 2.78% and 37.50%, a difference of about 35% over the same eight DNLs. This is shown in Table 4.5, which lists the same values that are plotted in Figure 4.1.

If the data plotted in Figure 4.1 changed with DNL and % highly annoyed at the same rate as the Schultz curve, the Schultz curve and the observed data could be described with a correlation coefficient of $r = 1$. This would be an ideal positive relationship. To determine the

Table 4.5 The observed percentage values of people highly annoyed at each DNL.*

	DNL 56	DNL 61	DNL 62	DNL 63	DNL 64
Schultz Prediction (values from regression)	4.57%	8.49%	9.57%	10.77%	12.11%
Overall Noise (observed values)	2.78	21.62	2.63	22.22	37.50
Fixed-wing Aircraft Noise (observed values)	5.88	12.12	2.86	12.00	12.50
Helicopter Noise (observed values)	20.69	39.39	13.51	23.08	43.75

*These are the five DNL categories in this study with more than 10 interviewed residents.

actual relationships, the correlation procedure needed to be performed three times; 1) between the Schultz curve and percent highly annoyed with overall noise, 2) between the Schultz curve and percent highly annoyed with fixed-wing aircraft noise and 3) between the Schultz curve and percent highly annoyed with helicopter noise. These correlations were performed using the values in Table 4.5.

The strongest relationship was between the Schultz curve and the percentage annoyed with overall noise ($r = 0.744$). The second strongest relationship was between the Schultz curve

and the percentage annoyed with fixed-wing aircraft noise (r = 0.508). The relationship was weakest between the Schultz curve and percentage highly annoyed with helicopter noise(r = 0.411). To summarize, at DNLs 56, 61, 62, 63, and 64, the Schultz curve correlated better with the percentage of people highly annoyed with overall noise than with the percentage highly annoyed with helicopter noise.

This information may seem encouraging for those managing environmental noise. For example, if the Schultz curve correlates best with overall noise annoyance, it appears to be predicting what it claims to predict. But, the correlation only provides information on rate of change, or slope. The correlation does not provide any information on the differences between the Schultz curve and the observed percentages of people annoyed at each DNL. To illustrate this point, visualize that the slope of two lines may be parallel (a correlation of r=1), but the lines may have a different intercept with the y axis. If one of the lines is higher than the other, the predictions for percentage of people highly annoyed at each DNL will be different than the observations made in this study. The correlations just assessed the slopes, but the forthcoming chi-square analyses can assess if there is a significant difference between the lines.

The Schultz curve should be useful for predicting the percentage of the population annoyed at each DNL. Since the question involves how the population living within each DNL is distributed on an annoyance scale, a chi-square analysis can provide the answer (Appendix F-6). Helicopter traffic planners will rarely confront the entire range of DNLs plotted in the Schultz curve. As in this study, they may be concerned with a few discontiguous DNLs in the mid-range.

The Schultz curve is derived from a regression. For that reason, it should be compared not only to the observed values in this study, but also to values derived from a regression on observed values. The regression values are more appropriate for this analysis because non-systematic variations would be difficult to interpret. From Figure 4.2 it appears that the regression curve on percentage of people highly annoyed with fixed-wing aircraft noise fits closer to the Schultz predictions than the percentage annoyed with helicopter noise. This was statistically verified as well. The best-estimated regression on values were compared to the Schultz values at each of the five DNLs.

Table 4.6 lists the best-estimated values derived from the regression on the observed values in Figure 4.2. The shaded squares are those categories in which the data collected in this study are significantly different from the Schultz prediction.

Table 4.6. The predicted percentage values of people highly annoyed at each DNL.

	DNL 56	DNL 61	DNL 62	DNL 63	DNL 64
Schultz Prediction (values from regression)	4.57%	8.49%	9.57%	10.77%	12.11%
Overall Noise (values from regression)	2.78	9.96	15.58	23.81	32.90
Fixed-wing Aircraft Noise (values from regression)	5.88	8.66	9.52	10.82	12.12
Helicopter Noise (values from regression)	20.35	35.11	27.27	31.17	35.93

Notice that in all of the categories in which the Schultz prediction failed to predict the observations made in this study, the Schultz prediction was too low. The Schultz curve appears to successfully predict the percentages of people annoyed with fixed-wing aircraft noise at these DNLs, but may predict levels that are too low for helicopters (Appendix N). Further study is

recommended to determine if the predicted levels should be elevated when planning for changes in helicopter noise.

To summarize, the Schultz curve was expected to:

- predict either the rate of change in the percentage highly annoyed with each change in dBA,
- or predict the percentage of the population annoyed at each dBA.

Using these two criteria, the preceding results reveal that the Schultz predictions do not match the observed or derived values of the percentage of the population highly annoyed with helicopter noise.

In this study, the Schultz curve best predicted the rate of change for overall level of annoyance with DNL. And, the Schultz curve best predicted the percentage of the population annoyed with the fixed-wing aircraft noise. But, the Schultz curve predictions appear less applicable to the percentage of the population highly annoyed with helicopter noise.

4.4 How did annoyance caused by helicopter noise compare with annoyance by other noise sources?

Residents' annoyance level with helicopter noise was significantly greater than their annoyance with fixed-wing aircraft noise. The prior section implied that annoyance with helicopter noise was high in the community surveyed in the present study. The following analyses confirm this. The two analyses included a broader range of DNLs and measured the average annoyance level, rather than the percentage highly annoyed. The first analysis was performed on pre-Olympic data. The second was performed on the during-Olympic data. The

analyses reveal that both prior to the Olympic Games and during the Olympic Games, the average level of annoyance with helicopter noise was significantly greater than the average level of annoyance with fixed-wing aircraft noise (Figure 4.3 and Appendix O).

Because annoyance with helicopters was high, it is likely that it related strongly to residents' level of annoyance with overall noise. In other words, it is unlikely that the residents could disregard their annoyance with helicopter noise, even when taking everything into consideration. This can be illustrated by considering several of the factors that might relate to a person's overall annoyance level. For example, the length of time a person had lived in the vicinity of the airport may have been a factor. Or perhaps their annoyance with car traffic related to how annoyed they were with overall noise. To determine how the level of annoyance with helicopters ranked among these other factors, both pre-Olympic and during Olympic data were analyzed.

On pre-Olympic data, a regression was performed between the dependent variable, level of annoyance with overall noise, and five independent variables, which included DNL, duration of residence, annoyance with fixed-wing aircraft noise, annoyance with car noise, and annoyance with helicopter noise. The multiple regression revealed that the five independent variables conclusively accounted for 44.5% of the variance (see Appendix P). This means that although other variables also contribute to residents' levels of annoyance, the five variables selected here contribute to a significant extent and are meaningful. The most meaningful are those with the greatest correlation coefficient, r. Table 4.7 lists the variables in order of their relationship to the overall level of annoyance. Before the Olympic Games, annoyance with helicopter noise had the highest correlation with overall annoyance.

Table 4.7 Correlations with overall annoyance for Group A; Pre-Olympic period.

Dependent Variable	Independent Variables	Correlation Coefficient
Overall Annoyance Level	Helicopter Annoyance	0.510
	Fixed-wing Aircraft Annoyance	0.412
	DNL	0.410
	Car Annoyance	0.188
	Duration at Address	-0.179

Similarly, the regression on the During-Olympic data included six independent variables which conclusively accounted for 34.2% of the variance (see Appendix Q). The six variables included DNL, change in DNL, duration of residence, annoyance with fixed-wing aircraft noise, annoyance with car noise, and annoyance with helicopter noise. The annoyance with helicopter noise had the highest correlation with overall annoyance (Table 4.8).

Table 4.8 Correlations to overall annoyance for Both Groups; During Olympic Games Period

Dependent Variable	Independent Variables	Correlation Coefficient
Overall Annoyance Level	Helicopter Annoyance	0.385
	Change in DNL	-0.271
	DNL	0.180
	Duration at Address	0.162
	Car Annoyance	-0.060
	Fixed-wing Aircraft Annoyance	-0.061

These correlations indicate that annoyance with helicopter noise is highly related to residents' annoyance with overall level of noise.

The analyses thus far indicated that the community's average level of annoyance with helicopter noise was higher than annoyance with fixed-wing aircraft. Analyses also demonstrated that annoyance with helicopter noise and overall noise share a relatively strong, positive relationship. In addition, a large segment of interviewed residents expressed annoyance with helicopter noise. Of those who noticed helicopter noise prior to the Olympic Games, 48% expressed slight or higher annoyance with helicopter noise. Of those who noticed helicopter noise during the Olympic Games, 50% expressed slight or higher annoyance with helicopter noise. The people who complained about helicopter noise appear to be broadly distributed across DNLs. Similar analysis of variance revealed no significant difference between the average annoyance levels with helicopter noise at each DNL prior to the Olympic Games. An analysis performed on the annoyance levels between DNLs on the data collected during the Olympic Games did reveal a significant difference. But, the mean levels of annoyance are rather non-systematic across DNL (Appendix R; Figure 4.4). The lack of annoyance at 72dBA was not expected, however, only 6 homes are in that area only 3 households were interviewed. Apparently, those three residents were not bothered by the noise. As mentioned earlier, even an analysis on the mean level of annoyance with helicopters between the eight categories of "change in DNL" failed to reveal a significant difference (Appendix M).

To summarize, about half of the community was annoyed with helicopter noise. These analyses indicate that the average level of annoyance with helicopter noise is significantly higher

than the average level of annoyance with fixed-wing aircraft. It also appears that annoyance with helicopter noise was a major factor when respondents stated their annoyance with the overall level of noise.

SECTION 5

5.0 CONCLUSIONS

The answers to the four questions addressed in this study imply that helicopter noise is one of the more salient noise sources in the neighborhoods. Therefore, any increases in helicopter noise should be managed conservatively.

5.1 Residents did notice the noise level increase during the Olympic Games.

GTRI noise measurements indicated the majority of the people interviewed experienced a 7 dBA increase in noise level. The community noticed the change in noise level during the Olympic Games, and with no prompting from the interviewer, 58.0% of the residents interviewed attributed the increased noise to an increase in helicopter traffic, 21.1% attributed the increased noise to air traffic, and 11.6% attributed the increased noise to both fixed-wing aircraft and helicopters.

If the hypothesis is "More residents will notice a change in the noise level if a helipad is placed at an existing general aviation airport," this report offers strong evidence in support of the hypothesis.

5.2 Residents' annoyance levels did not increase during the Olympic Games.

Although the community noticed a change in noise, they did not become more annoyed with overall noise or with helicopter noise. This could be misleading because 48% of those who noticed helicopter noise were already annoyed before the increased DNLs.

If the hypothesis is "Residents annoyance levels will remain the same if a helipad is placed at an existing general aviation airport," this report offers no contradictory evidence.

However, planners are cautioned against accepting the hypothesis as stated above strictly on the basis of this report. It is possible that this study failed to detect the human-response consequences of a long-term change on annoyance levels. It is quite possible residents were more tolerant because they knew the noise would subside with the end of the Olympic games.

5.3 The Schultz curve predictions vary from the percentages annoyed with helicopter noise.

If the Schultz curve is to be useful in future planning,

- it should predict the rate of change in the percentage highly annoyed with each change in dBA,
- or it should predict the percentage of the population annoyed at each dBA.

Within the range of 56 through 64 DNL, the Schultz curve predicts about a 1% increase in percentage of people highly annoyed for each unit increase in DNL. This prediction only had a correlation coefficient of $r = 0.411$ with the percentage of people highly annoyed with helicopter noise at those DNLs in this study.

Also, the highly annoyed population percentages predicted by the Schultz regression at DNLs 56, 61, 62, 63, and 64 are all significantly lower than the percentages of residents annoyed with helicopter noise from this study. This may be because the Schultz curve was intended for annoyance with overall noise, not specific sources of noise.

Although this study includes small numbers of residents over a small range of DNLs, the Schultz curve did not successfully predict annoyance with helicopter noise.

5.4 Annoyance due to helicopters is higher than annoyance caused by fixed-wing aircraft noise.

The community's average level of annoyance with helicopter noise is higher than "slightly annoyed." This level is significantly greater than the average level of annoyance with fixed-wing aircraft noise which is right at "slightly annoyed." In this study, level of annoyance with helicopter noise and overall noise annoyance shared the greatest relationship, which suggests that helicopter noise is too salient for residents to disregard when taking everything in their neighborhood into consideration.

SECTION 6

6.0 RECOMMENDATIONS FOR FUTURE STUDY

The investigation of noise annoyance following the "Levels Document" in 1974 has brought to the front many questions on the acquisition of noise data and interpretation of survey results. Questions have been raised on the most appropriate noise metric, differential protective levels from various sources, and the effect of people's attitude toward a noise source on survey results. This has left room for a wide variety of studies to be done in the future to settle these discrepancies. The following are some areas that should form future studies:

1. More research should be done on the effects of noise characteristics on a community including the effects of lower frequencies, impulsive sounds, duration, and the number of occurrences of various noise sources.

2. Develop some widely accepted standards in survey structure and questions so that the results may be more readily compared with a higher degree of accuracy.

3. Conduct more studies with controlled sources of noise annoyance as it was in Fields and Powell's[19] helicopter study and hide the objective of the survey from the participants. These studies should be performed on other transportation devices such as fixed-wing aircraft and trains in order to have a more controlled method of determining the difference in annoyance levels toward different transportation types.

4. In order to determine the effect of house vibration or rattling in the annoyance level associated with helicopters, noise measurements should be taken inside a person's home and the level of annoyance should be compared to the level of annoyance of participants who spend the majority

of their time outside and are exposed to the same level of noise. This data should be correlated to specific flight trajectory (i.e., glide slope, turns, and speeds).

5. Studies should be done to compare the effect of a particular level of fixed-wing aircraft activity in areas of varying ambient noise levels. For instance: quiet, rural area vs. neighborhood near a large street vs. city environment. These studies will determine the effects of the level of ambient noise on annoyance caused by a specific source.

6. Studies should also be done on varying types of ambient noise, for instance the difference between an area where the main source of ambient noise is street traffic vs. an area where the ambient noise level is caused by nature sounds such as birds and insects.

7. Studies should be conducted of the effect of noise of helicopters, fixed-wing aircraft, road traffic, and trains on communities of similar ambient noise backgrounds where the source of noise in question is isolated from the others. For instance take helicopter and fixed-wing aircraft measurements on dead-end roads and circles away from rail lines, other noises and airports. If all studies are conducted under similar situations with a standard survey, the answers can be accurately compared to establish what noise sources are most bothersome and what predictive laws should be used for each to predict annoyance.

8. The design parameters for helicopters should be investigated to determine their contribution to noise profile.

9. Terrain and structures have influence on noise patterns experienced on the ground. Contributions of each should be investigated to quantify.

SECTION 7

7.0 REFERENCES

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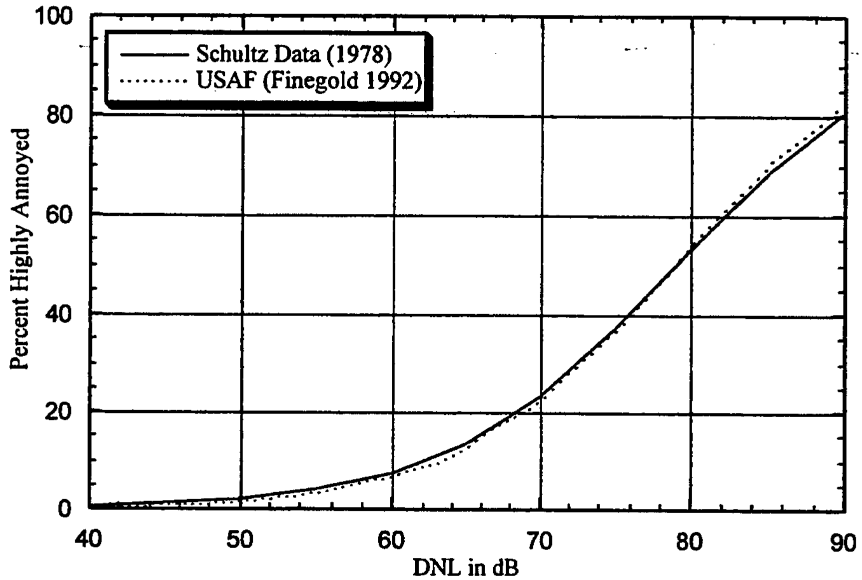


Figure 2.1 Comparison of Schultz Curve and Study Done by USAF.

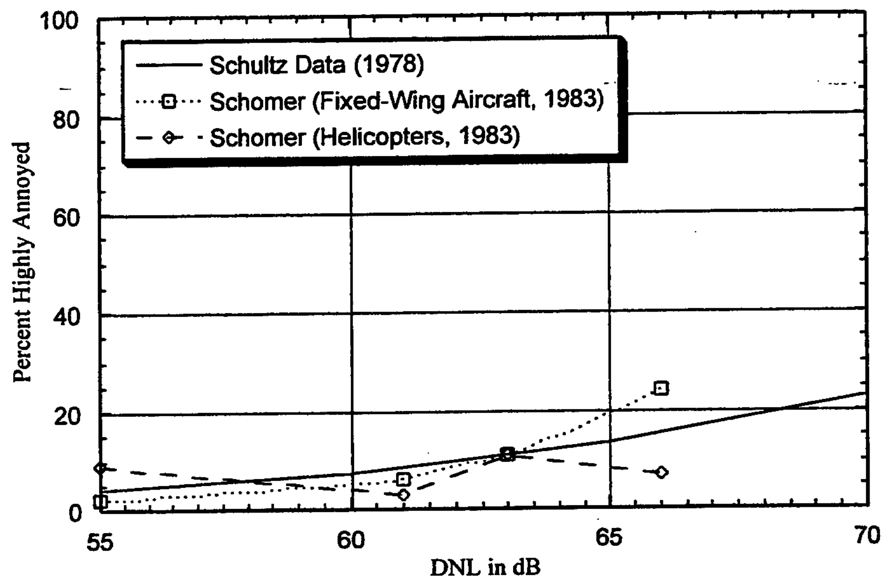


Figure 2.2 Comparison of Shultz Curve to study by Schomer on helicopters and fixed-wing aircraft.

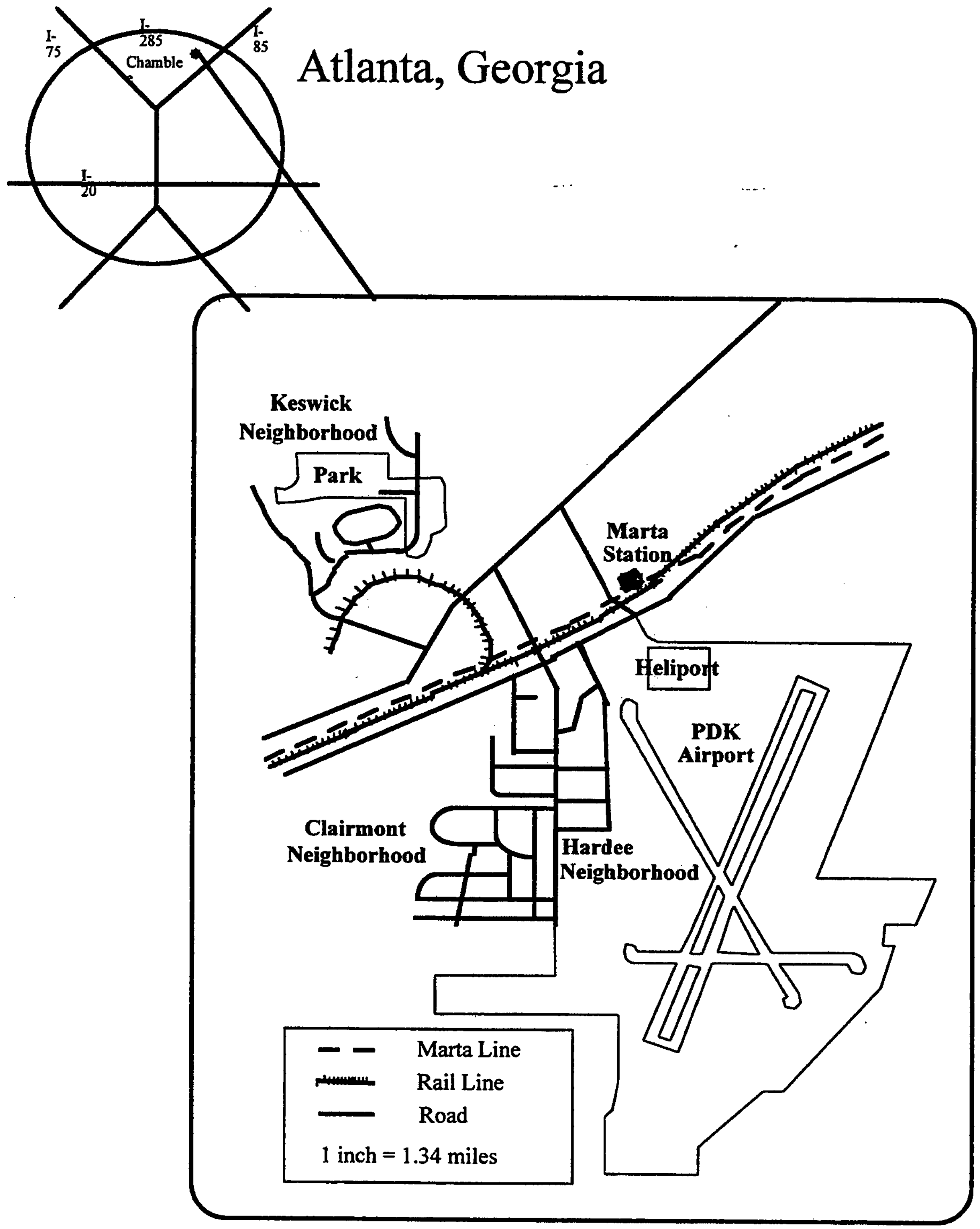


Figure 3.1. Neighborhood Locations with Respect to the Airport, Marta Line, and Railroad Tracks

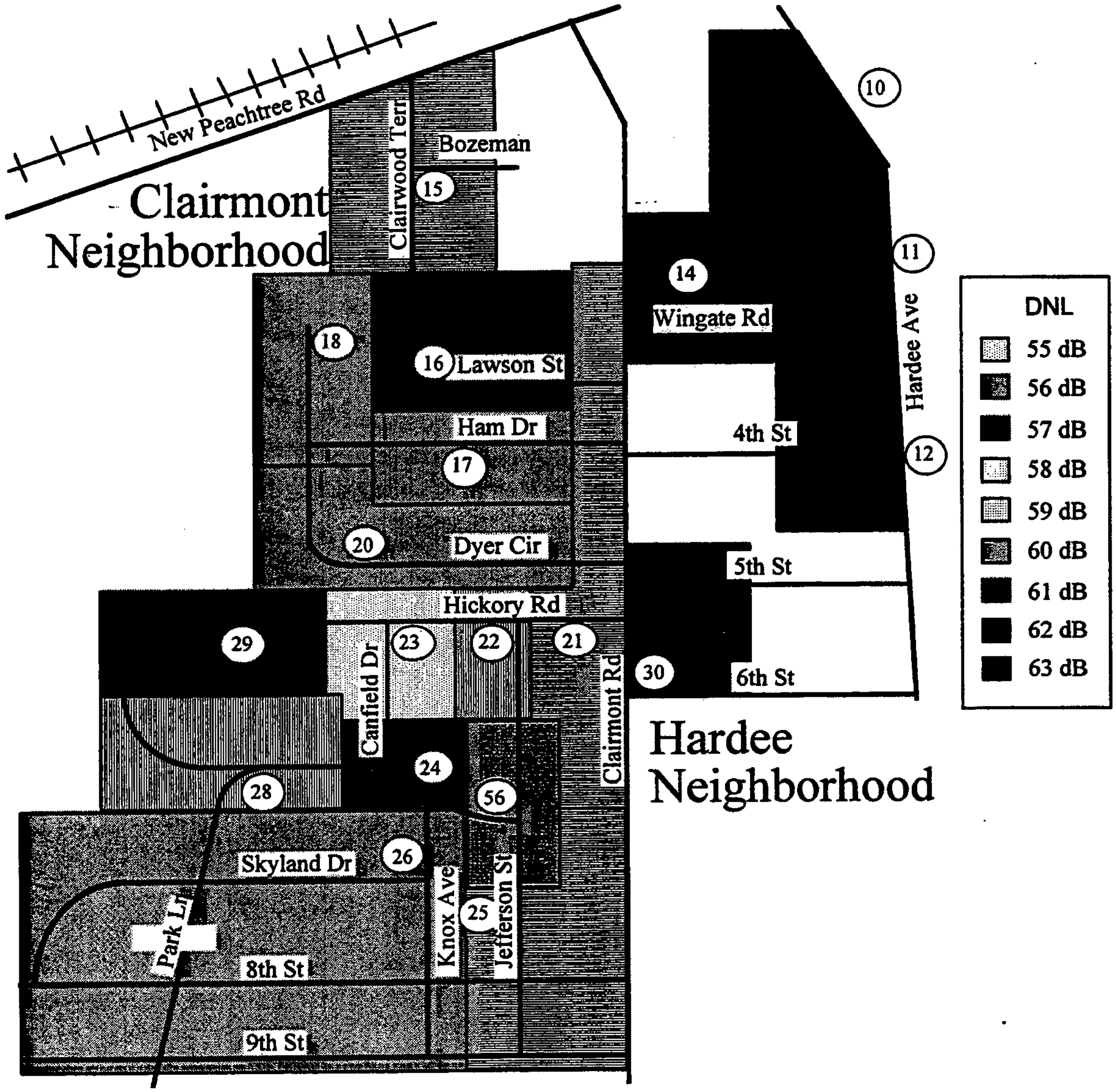


Figure 3.2 DNLs During Pre-Olympic Phase in the Clairmont and Hardee Neighborhoods

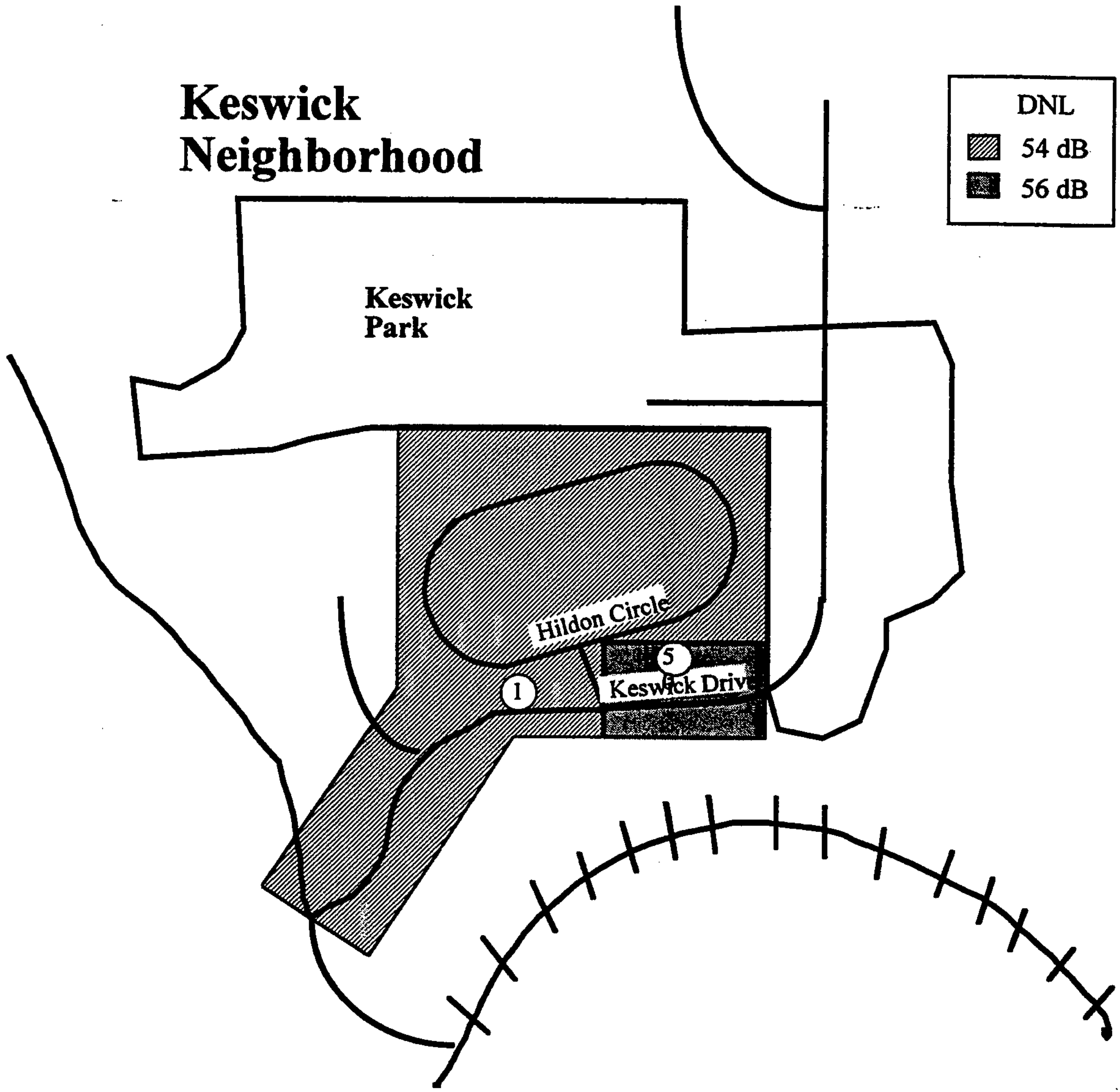


Figure 3.3 DNLs During Pre-Olympic Phase in the Keswick Neighborhood

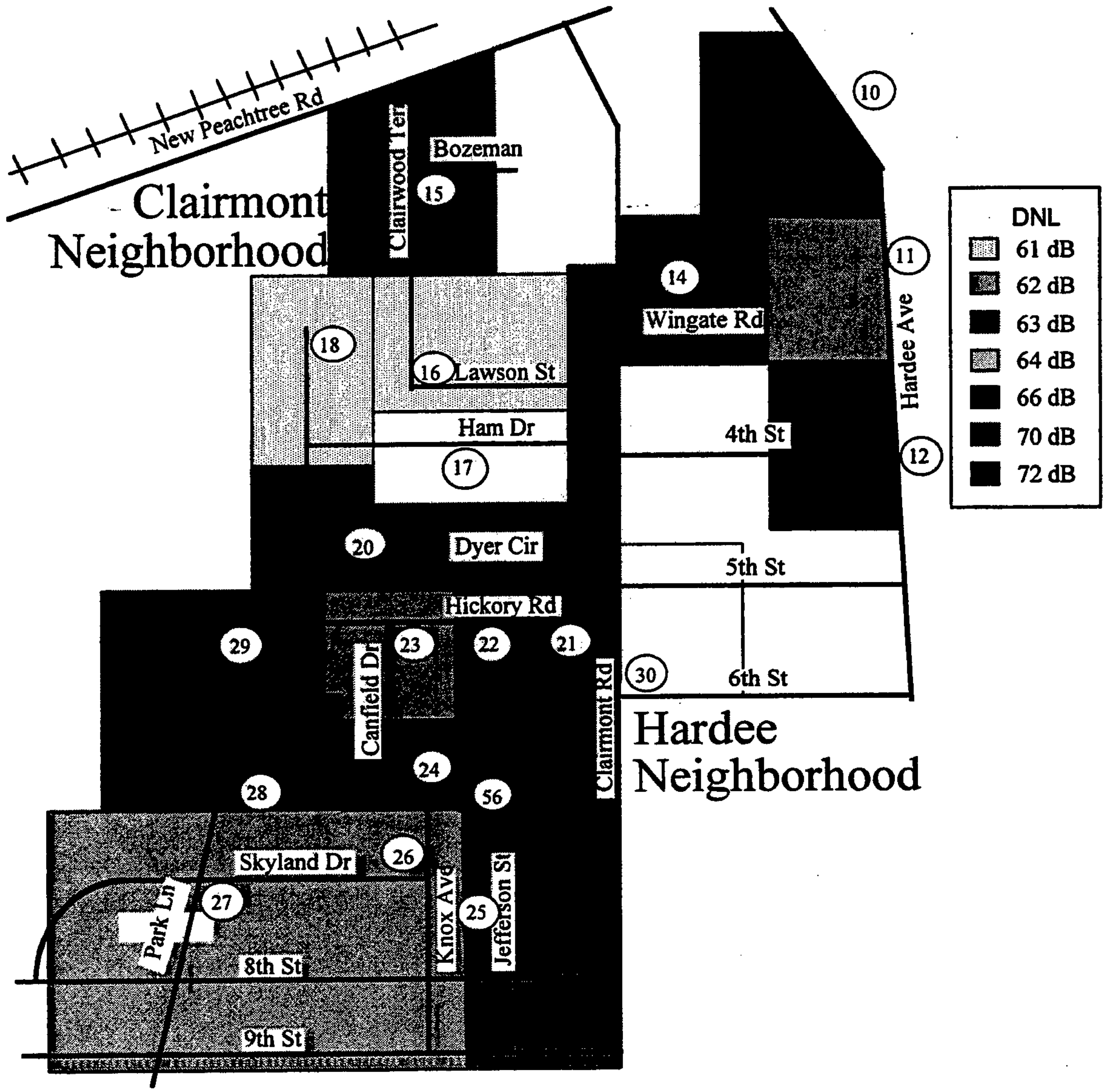


Figure 3.4 DNLs During Olympic Phase in the Clairmont and Hardee Neighborhoods

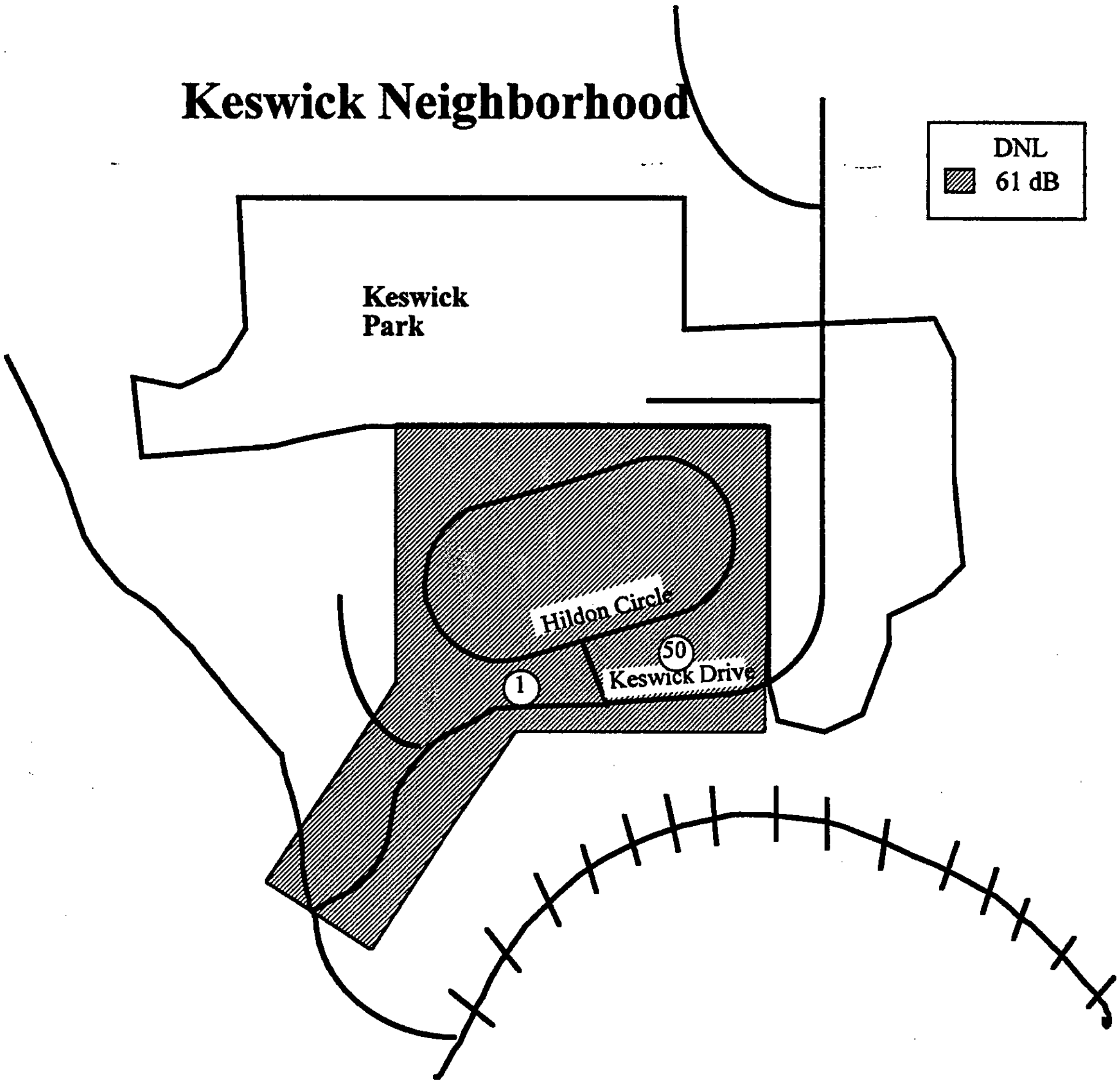
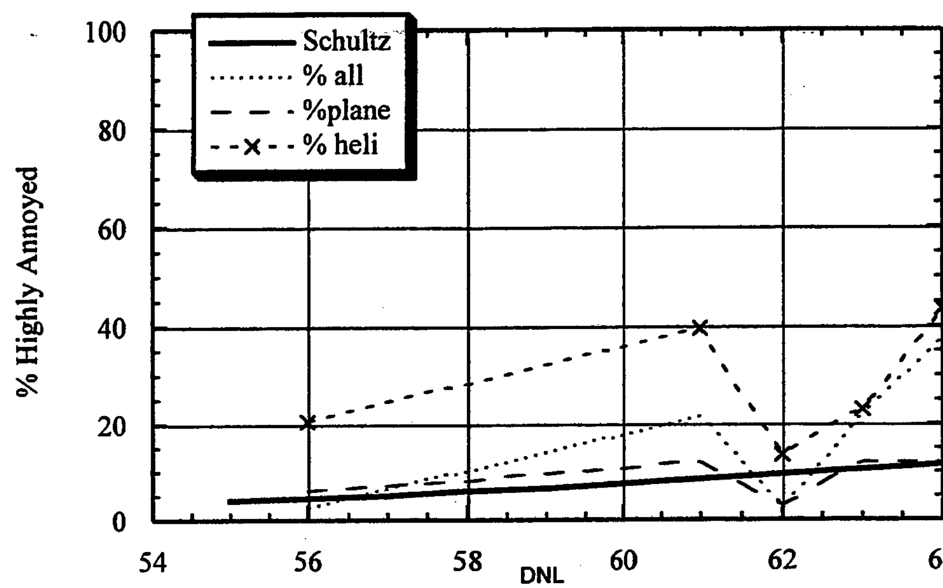
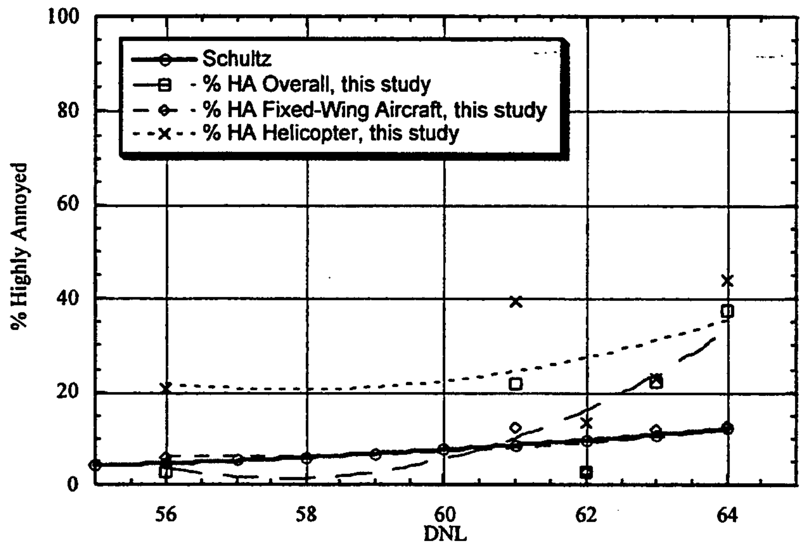


Figure 3.5 DNLs During Olympic Phase in the Keswick Neighborhood



DNL	55	56	57	58	59	60	61	62	63	64
Schultz		4.57					8.49	9.57	10.77	12.11
# at Location		36					37	38	27	16
% HA Overall		2.78					21.62	2.63	22.22	37.50
% HA Aircraft		5.88					12.12	2.86	12.00	12.50
% HA Heli		20.69					39.39	13.51	23.08	43.75

Figure 4.1 Percentage highly annoyed with overall noise, fixed-wing aircraft noise, and helicopter noise vs. DNL with Schultz curve for reference.



DNL	55	56	57	58	59	60	61	62	63	64
Schultz		4.57					8.49	9.57	10.77	12.11
# at Location		36					37	38	27	16
%HA Overall		2.78					9.96	15.58	23.81	32.9
%HA Aircraft		5.88					8.66	9.52	10.82	12.12
%HA Heli		20.35					35.11	27.27	31.17	35.93

Figure 4.2 Percentage highly annoyed with overall noise, fixed-wing aircraft noise, and helicopter noise vs. DNL with Schultz Curve for reference.

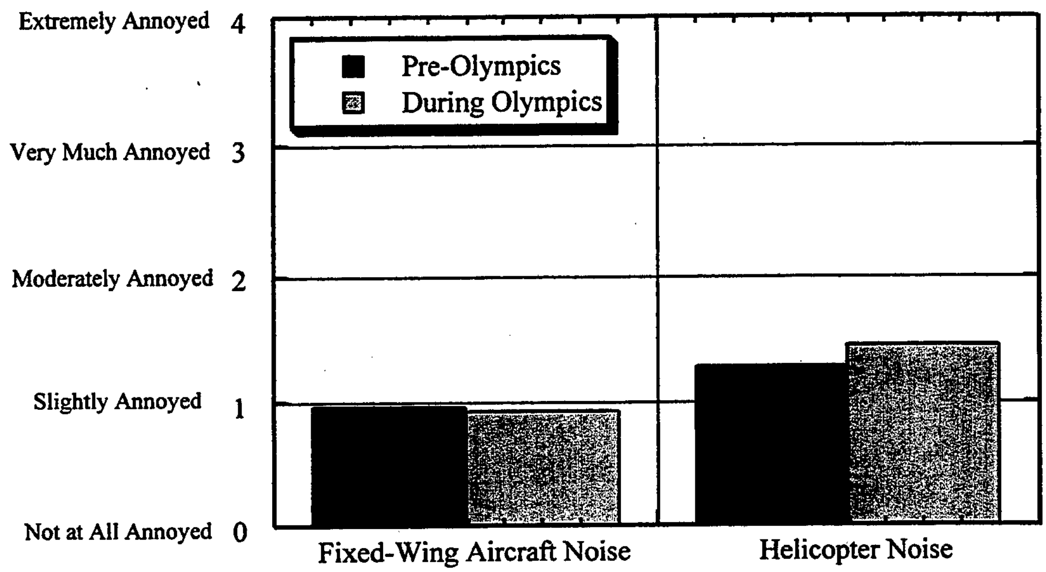


Figure 4.3 Comparison of mean annoyance level for fixed-wing aircraft and helicopters.

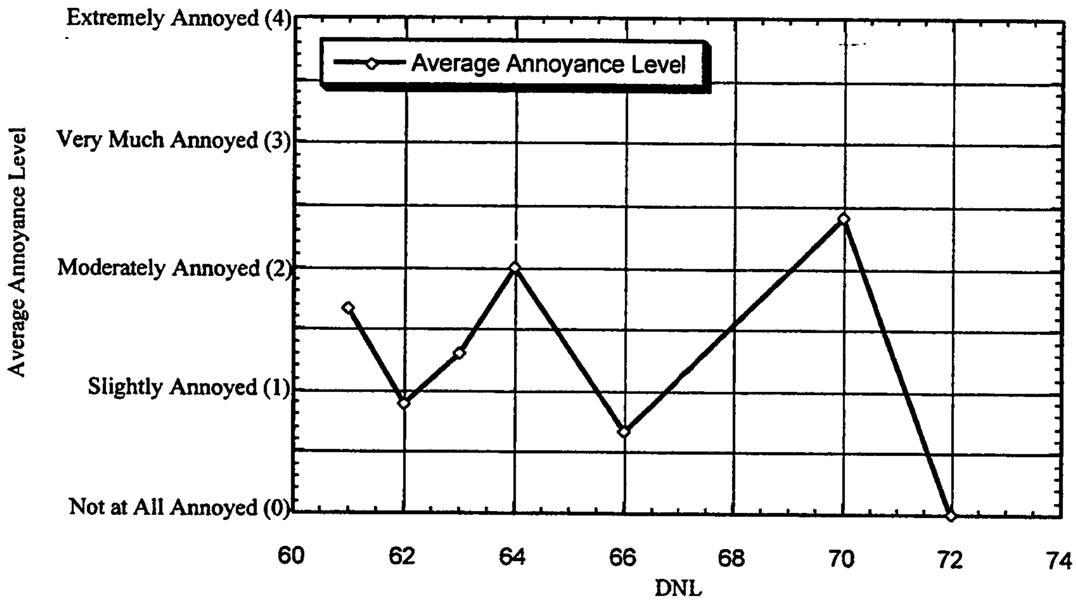


Figure 4.4 Average level of annoyance with helicopters during the Olympics by DNL

Appendix A: Number of occurrences of specific noise events at each measurement site during the Olympic period.

Measurement Location Number	DNL	Change in DNL	Date	Helicopter	Light Plane	Turboprop	Jet	Truck	Marta	Train	Car
16	61	4	7/22/96	120	46	3	48	42	113	4	152
18	61	5	7/22/96	113	51	0	52	8	53	7	18
50	61	5	7/24/96	143	65	3	43	2	0	0	little
11	62	-1	7/26/96	294	59	26	137	89	24	5	about 50/hr
17	62	6	7/22/96	108	56	20	53	17	4	2	72
23	62	7	7/23/96	88	34	17	13	27	15	1	every 3-6 min
26	62	6	7/24/96	98	80	26	51	4	38	0	80
30	62	0	7/22/96	81	37	16	53	44	4	2	constant till 9, 18 after 9
15	63	4	7/22/96	120	46	3	48	42	113	4	152
20	63	7	7/23/96	104	47	4	15	6	3	4	21
28	63	5	7/24/96	97	101	9	22	28	0	0	53
29	63	6	7/23/96	159	99	7	41	8	73	0	82
56	63	3	7/23/96	126	82	8	82	10	41	7	111
14	64	3	7/24/96	142	44	5	22	16	0	0	constant
21	64	5	7/23/96	143	55	11	19	5	23	0	191
22	64	6	7/23/96	143	55	11	19	5	23	0	191
24	64	7	7/26/96	116	74	9	92	6	0	42	76
25	66	7	7/23/96	126	82	8	82	10	41	7	111
10	70	7	7/24/96	142	44	5	22	16	0	0	constant
12	72	10	7/26/96	294	59	26	137	89	24	5	about 50/hr
1*	no recordings were made.										

Appendix B: Letter sent to the community requesting interviews.

July 10, 1996

Dear Community Member,

We are Georgia Institute of Technology students who are conducting a study of neighborhood acoustic environments. Our intention is to summarize some impressions people have within the metro-Atlanta area.

Your neighborhood is an area of interest to us. Would you volunteer to meet with us for five minutes sometime in the next several weeks?

We will contact residents sometime between Thursday, July 11 and Wednesday, August 21, 1996. We will come by your house and ask you to volunteer to answer several questions at that time. We have Georgia Tech Research Institute badges and we will never ask to come inside your home. The questions can be answered at your doorstep. Your answers will be confidential. The number of questions has been timed and they take no more than five minutes to discuss.

Please consider participating in this study. A majority of your community is needed in order for us to learn the most and to develop an accurate report on neighborhood environments.

If you have any questions, you can call Professor Krish Ahuja of the School of Aerospace Engineering at Georgia Institute of Technology, 770-528-7054. He can also be contacted at Home, 404-255-7416. Sherry Travis, Dr. Ahuja's Administrative Secretary, is also at 770-528-7054 and can be contacted to verify our identity.

Thank you in advance.

Sincerely,

Ms. Marcie Benne
Graduate Research Assistant,
School of Psychology

Ms. Mary Lyn Rivamonte
Undergraduate Research Assistant
School of Aerospace Engineering

Appendix C: Pre-Olympic Survey Questionare

Community Survey
Interviewer's Script
A) "We are students at Georgia Tech and we are assessing the environment of selected communities within Atlanta. Within the next two months, we hope to get responses from the majority of you living in this neighborhood. We would appreciate it if you would volunteer *5* minutes right now to answer our questions. The responses to this quesitonnaire will never be associated with your name and are completely confidential."

If they say ok, continue to B). If they say no, ask them,
"Is there another time we could come back to learn what you think about your neighborhood?"
If they say yes, record time and day here:
____
Say "Thank you."

B) *Say* "Thank you. There are 15 questions to answer and several have rating scales."

1) How long have you lived at this address? ________________________

Interviewer say:
"Ok. As you answer these questions, use only your impressions from only this past week.
That would be between last __________ (ex: Tuesday) and today (ex Tuesday)."

2) "What do you enjoy most about your neighborhood (within a two or three block radius of home)?"
____

3) "What are some of the things about your neighborhood that are bothersome to you?"
____

4) "Does the level of noise in your neighborhood bother you?"

Yes	No	Don't Know
1	2	8

If yes, "Please rate the level to which it bothers you."

Extremely	Very Much	Moderately	Slightly
1	2	3	4

5) "Have you noticed any changes in the noise level in your neighborhood?"

Yes	No	Don't Know
1	2	8

If "yes," ask,
"What changes have you noticed and when did they occur?"
What ____________________________________
When ____________________________________

6) "What days and times do you hear noise in your neighborhood?"

Weekdays (1)				Weekends (2)			
Morning (11)	Aftnoon (12)	Evening (13)	Night (14)	Morning (21)	Aftnoon (22)	Evening (23)	Night (24)

Interviewer should note what they say and then repeat back what you've circled in order to confirm.

7. "What are some sounds you notice in your neighborhood?" *Rank in order mentioned.*	8. *For noises not mentioned:* "Do you ever hear noise from ______ when at home or in your neighborhood?"	9a. "In general, taking everything into consideration, does the noise from ______ ever bother or annoy you?"	9b. *If yes:* "Overall, how annoyed are you by the noise from the ______? Would you say...."	10. *For each noise heard:* "How loud is noise from ______ compared to normal conversation? It is ..."	11. "How often do you hear noise from ______?"
	Yes *No*	*Yes* *No* *DK = Don't Know.*	*E = Extremely* *VM = Very Much* *M = Moderately* *S = Slightly*	*M = Much Louder* *L = Louder* *S = About the same* *Q = Quieter* *MQ = Much quieter* *DK = Don't Know*	*ED = Everyday* *(__) Fill in how many times.* *s/w = Several times per week.* *s/m Several times per month.* *s/y = Several times a year.* *Less = Less often than that.* *DK = don't know.*
	yes no	yes no dk	4 3 2 1 E VM M S	5 4 3 2 1 8 ML L S Q MQ DK	5 4 3 2 1 8 ED s/w s/m s/y less DK
Cars ___	1 2	1 2 3	4 3 2 1	5 4 3 2 1 8	5(__)4 3 2 1 8
Trucks ___	1 2	1 2 3	4 3 2 1	5 4 3 2 1 8	5(__)4 3 2 1 8
Airplanes ___	1 2	1 2 3	4 3 2 1	5 4 3 2 1 8	5(__)4 3 2 1 8
Helicopters ___	1 2	1 2 3	4 3 2 1	5 4 3 2 1 8	5(__)4 3 2 1 8
Trains ___	1 2	1 2 3	4 3 2 1	5 4 3 2 1 8	5(__)4 3 2 1 8

Other (specify) ______ ___	1 2	1 2 3	4 3 2 1	5 4 3 2 1 8	5(__)4 3 2 1 8
Other (specify) ______ ___	1 2	1 2 3	4 3 2 1	5 4 3 2 1 8	5(__)4 3 2 1 8

DV

12. Does the noise made by the crickets in your area bother you?

Yes No Don't Know

13. Does the noise from birds in the neighborhood bother you?

Yes No Don't Know

*14. "Would you be willing to tell me your age?"

18-25	26-30	31-35	36-40	41-45	46-50	
51-55	56-60	61-65	66-70	71-75	76-80	80 and above

15. "Have you used an air conditioner in the past week while you have been home?"

No	Some	Continuously	Don't Know
1	2	3	8

Interviewer say:

"Thank you very much for volunteering. Again, this is a student project at Georgia Tech and your answers are confidential. To gather the best sample of data, we would like to interview the majority of the volunters in this neighborhood more than once. Would you be willing to answer our questions again later this summer? The questions will never last more than 5 minutes."

Yes	No	Maybe/Don't Know

"Thank you."

END OF INTERVIEW**

(Don't ask this, just note it) *Gender* Female Male 1 2	*(Don't ask this either)* **Type of housing* single family multi family 1 2 **siding type* wood alum asbestos/masonite brick other 1 2 3 4 5	*(Don't ask this either)* Address: ______________________ ______________________

Group: A B C
Nearest SLM ____________
Time interview ended: _______________
Interview Date: _____________________
Interviewer Name: _________________

These questions were compiled with reference to Schomer (1983).

Appendix D: During Olympics Survey Questionare.

Community Survey

Interviewer's Script

A) "We are students at Georgia Tech and we are assessing the environment of selected communities within Atlanta. Within the next two months, we hope to get responses from the majority of you living in this neighborhood. We would appreciate it if you would volunteer *5* minutes right now to answer our questions. The responses to this quesitonnaire will never be associated with your name and are completely confidential."

If they say ok, continue to B). If they say no, ask them,

"Is there another time we could come back to learn what you think about your neighborhood?"

If they say yes, record time and day here:

Say "Thank you."

B) *Say* "Thank you. There are 15 questions to answer and several have rating scales."

1) How long have you lived at this address? ________________________________

Interviewer say:

"Ok. As you answer these questions, use only your impressions from only this past week.
That would be between last ____________ (ex: Tuesday) and today (ex Tuesday)."

2) "What do you enjoy most about your neighborhood (within a two or three block radius of home)?"

3) "What are some of the things about your neighborhood that are bothersome to you?"

4) "Does the level of noise in your neighborhood bother you?"

Yes	No	Don't Know
1	2	8

If yes, "Please rate the level to which it bothers you."

Extremely	Very Much	Moderately	Slightly
4	3	2	1

5) "Have you noticed any changes in the noise level in your neighborhood?"

Ye	No	Don't Know

S		
1	2	8

If "yes," ask,
"What changes have you noticed and when did they occur?"
What ______
When ______

6) DELETED

7. "What are some sounds you notice in your neighborhood?" *Rank in order mentioned.*	8. *For noises not mentioned*: "Do you ever hear noise from ______ when at home or in your neighbor hood?"	9a. "In general, taking everything into consideration, does the noise from ______ ever bother or annoy you?"	9b. *If yes:* "Overall, how annoyed are you by the noise from the ______? Would you say...."	10. *For each noise heard:* "How loud is noise from ______ compared to normal conversation? It is ..."	11. "How often do you hear noise from ______?"	11.5 "How often do you see ______ when you hear it?
	<u>*Yes*</u> <u>*No*</u>	Yes No DK = Don't Know.	<u>E</u> = Extremely <u>VM</u> = Very Much <u>M</u> = Moderately <u>S</u> = Slightly	<u>M</u> = Much Louder <u>L</u> = Louder <u>S</u> = About the same <u>Q</u> = Quieter <u>MQ</u> = Much quieter <u>DK</u> = Don't Know	<u>ED</u> = Everyday (__) Fill in how many times. <u>s/w</u> = Several times per week. <u>s/m</u> Several times per month. <u>s/y</u> = Several times a year. <u>Less</u> = Less often. <u>DK</u> = don't know.	U: usually O: Often S: Sometimes R: Rarely N: Never DK: Don't Know
	yes no	yes no dk	4 3 2 1 E VM M	5 4 3 2 1 8 M L S Q MQ Dk	5(__)4 3 2 1 8 Ed Sw Sm Sy Less Dk	5 4 3 2 1 8 U O S R N DK

			S			
Cars __	1 2	1 2 3	4 3 2 1	5 4 3 2 1 8	5(__)4 3 2 1 8	5 4 3 2 1 8
Trucks __	1 2	1 2 3	4 3 2 1	5 4 3 2 1 8	5(__)4 3 2 1 8	5 4 3 2 1 8
Airplanes __	1 2	1 2 3	4 3 2 1	5 4 3 2 1 8	5(__)4 3 2 1 8	5 4 3 2 1 8
Helicopters __	1 2	1 2 3	4 3 2 1	5 4 3 2 1 8	5(__)4 3 2 1 8	5 4 3 2 1 8
Trains __	1 2	1 2 3	4 3 2 1	5 4 3 2 1 8	5(__)4 3 2 1 8	5 4 3 2 1 8
Other (specify) ________	1 2	1 2 3	4 3 2 1	5 4 3 2 1 8	5(__)4 3 2 1 8	5 4 3 2 1 8
Other (specify) ________	1 2	1 2 3	4 3 2 1	5 4 3 2 1 8	5(__)4 3 2 1 8	

12. Does the noise made by the crickets in your area bother you?
Yes No Don't Know
13. Does the noise from birds in the neighborhood bother you?
Yes No Don't Know

*14. "Would you be willing to tell me your age?"

18-25	26-30	31-35	36-40	41-45	46-50	
51-55	56-60	61-65	66-70	71-75	76-80	80 and above

15. "Have you used an air conditioner in the past week while you have been home?"

No	Some	Continuously	Don't Know
1	2	3	8

16. "By the way, has the noise from the blimp bothered you in the past week?"

Yes	No	Don't Know
1	2	8

If yes, "How much has it bothered you?"

Extremely	Very Much	Moderately	Slightly
4	3	2	1

Interviewer say:

"Thank you very much for volunteering. Again, this is a student project at Georgia Tech and your answers are confidential. To gather the best sample of data, we would like to interview the majority of the volunteers in this neighborhood more than once. Would you be willing to answer our questions again later this summer? The questions will never last more than 5 minutes."

Yes	No	Maybe/Don't Know

"Thank you."

END OF INTERVIEW**

(*Don't ask this, just note it*)	(*Don't ask this either*)	(*Don't ask this either*)
Gender Female 1 Male 2 Was this the same person as last time? Yes No	*Type of housing single family 1 multi family 2 **siding type* wood 1 alum 2 asbestos/masonite 3 brick 4 other 5	Address: ____________________

Group: A B C

Nearest SLM __________

Time interview ended: __________

Interview Date:______________

Interviewer Name: ____________

These questions were compiled with reference to Schomer (1983).

Appendix E: Possible answers and numerical codes used in statistical calculations.

Question #	Possible answers and corresponding numerical codes used in statistical calculations						
1	< 1 month	< 1 year	< 2 years	< 5 years	< 10 years	< 40 years	> 40 years
	0	1	2	3	4	5	6
2	Quiet	Neighbors	Location	Safety	Nature	Other	
	0	1	2	3	4	5	
3	Air Traffic	Noise	Crime	Sirens	Street Traffic	Other	Helicopters
	0	1	2	3	4	5	6
5a	Yes	No	Don't Know				
	1	2	8				
5b	Slightly	Moderately	Very Much	Extremely			
	1	2	3	4			
6a	Yes	No	Don't Know				
	1	2	8				
6b	Helicopters	Air Traffic	Blimps	Less Noise	Both 0 and 1	Other	
	0	1	2	3	4	5	
7/8	Rank 7	8 Yes	8 No				
	1-9	11	12				
9	No	Slightly	Moderately	Very Much	Extremely		
	1	2	3	4	5		
10	Much Quieter	Quieter	Same	Louder	Much Louder		
	1	2	3	4	5		
11	Less	S/Y	S/M	S/W	Every Day		
	1	2	3	4	5		
11.5	Always	Usually	Sometimes	Rarely	Never		
	1	2	3	4	5		
12	Yes	No	Don't Know				
	1	2	8				
13	Yes	No	Don't Know				
	1	2	8				
14	18-25	26-30	31-35	36-40	41-45	46-50	51-55
	18	26	31	36	41	46	51
14 (cont'd)	56-60	61-65	66-70	71-75	76-80	80 and above	
	56	61	66	71	76	80	
15	No	Some	Continuously	Don't Know			
	1	2	3	8			
16	Yes	No	Don't Know				
	1	2	8				

Appendix F

Glossary of Statistics

The results in this paper were obtained using commercially available statistical software. The descriptive statistics included derivation of sample mean, frequency distribution, variance and correlation coefficient. The statistical analyses included multiple regression, analysis of variance (AVOVA), and chi-square tests. The reader is referred to a textbook of statistics for detailed descriptions of these statistical procedures. Conceptual descriptions appear below.

F-1. *Sample mean or average* ($\bar{x}$).

The following equation is used to determine the sample mean:

$$\bar{x} = \frac{\Sigma x}{n}$$

Where: n = the number of observations made in the experiment,

x = the value of each observation.

This is the best estimate (parameter) of a population's dependent variable, x, because it limits the amount of total variability between the parameter and the observations.

F-2. *Average Level of Annoyance*.

Within this study, the average, or mean, level of annoyance for a population was calculated from a five point Likert scale. The Likert scale contained the following points:

Not at All Annoyed	Slightly Annoyed	Moderately Annoyed	Very Much Annoyed	Extremely Annoyed
0	1	2	3	4

The residents' responses were given a code, 0, 1, 2, 3 or 4. In the case that the codes were entered into the computer on a 1 - 5 scale instead of a 0 - 4 scale, the codes were transformed to a 0, 1, 2, 3, and 4 before analysis. The average level of annoyance was calculated by adding all the codes together and dividing by the number of respondents to that question.

F-3. *Frequency Distribution for Percent Highly Annoyed*.

Theodore Schultz initiated this variation on frequency distributions and it has become a common metric in community noise studies. *"Highly annoyed"* refers to the top of the response scale participants used for rating annoyance. When the response scale was based on categories such as "not at all annoyed" to "extremely annoyed" Schultz used the categories he felt represented the "percent highly annoyed." For instance on a five-point scale including "not at all annoyed", "slightly annoyed", "moderately annoyed", "very much annoyed", and "extremely annoyed", he would count the top two categories as "percent highly annoyed."

The Percent Highly Annoyed (% HA) in this study was determined by counting the number of participants who answered the question "How much does the noise from <u>*the source*</u> bother you?" with "very much" or "extremely" (the top two levels on the scale), dividing that by the total number of participants in that DNL and multiplying by 100 to get a percent. This %

HA was plotted versus DNL to achieve a graph comparable to the Schultz curve and other studies using this standard.

F-4. *Variance (s^2).*

Variance is the deviation of each observation of the dependent variable, $\bar{x}$, from the mean. It can be a meaningful measure of consistency. The deviations are squared. The squared deviations are then added together and divided by the total number of observations. The equation for variance is:

$$s^2 = \frac{\Sigma\left(x - \overline{x}\right)^2}{n}$$

Where: n = the number of observations in the sample,

x = the values of the observations,

$\overline{x}$ = the sample mean.

Variance is not directly calculated in this study, but variance is utilized in the regression analyses and the analyses of variance described below.

F-5. *Hypothesis Testing and the p-value* .

There are five steps to hypothesis testing. The steps below offer conceptual descriptions. A reader is referred to a statistical textbook for extensive mathematical background.

Step 1. Formulate a null and an alternative hypothesis.

The *null* hypothesis (H_0) is the hypothesis stating that *no effect* on the dependent variable has occurred. It implies no change has occurred in the variable or it implies no difference exists between two variables.

The alternate hypothesis (H_1) is the hypothesis stating that a significant change or difference has occurred.

No hypothesis can be proven, but a null hypothesis can be rejected. In the case that it is rejected, the alternate hypothesis can be accepted. In the case that it can not be rejected, an investigator merely states that she has failed to reject the null hypothesis. The results in the appendices of this study state the null and alternate hypothesis for each analysis.

Step 2. Decide on the level of certainty.

An investigator can set the critical point at which the null will be rejected. This critical point can be thought of in terms of certainty. For example, an investigator might want to be 90% certain that rejecting the null is the appropriate action. Sometimes investigators want to be 95% certain and sometimes 99% certain. This is a judgment each investigator must make according to the circumstances. In this study, all decisions to reject null hypotheses are made with greater than 95% certainty. The level of certainty can be ascertained from both the test statistic that will result from the analysis in **Step 3** and from the probability value calculated in **Step 4**. In this study, the level of certainty is most often discussed in terms of the probability value.

Step 3. Decide on the type of analysis and perform the analysis.

The χ^2 analyses, regression analyses, and analyses of variance can be used to test for a rejection of the null hypothesis. Each of these analyses are described further below. The investigator chooses which of these analyses are appropriate for each hypothesis. All of the analyses derive a test-statistic (chi-square, F or R^2) which is checked against the level of certainty. This is done by determining if the test statistic falls outside 95% of the area

encompassed by a distribution of values which would be observed simply due to chance. This comparison requires some extensive explanation, which follows in Step 4 because a conceptually similar comparison is made for probability values. The results in the appendices of this study list the derived test-statistic.

Step 4. Calculate the probability-value.

The probability value is the proportion of a distribution that is beyond a particular test-statistic (chi-square, F or R^2).

Consider that the null hypothesis predicts that no change in the dependent variable will occur. However, changes in the dependent variable could occur simply because of chance. In this case, a certain range of values might well fall into a distribution around the observed dependent variable and subsequently around the derived test statistic (chi-square, F or R^2) which are simply due to chance. An investigator needs to determine what is a chance difference and what is a significant difference. The probability value will help make this determination.

If a value which might have occurred simply due to chance, then the investigator fails to reject the null hypothesis. 100% of all possible chance values can be described by a distribution based on the number of observations in the study and on the number of categories (or independent variables). The investigator then just needs to check if the test statistic derived in Step 3 is within this distribution of chance values.

Theoretically, the distributions asymptote and include all values to infinity. 95% certainty allows for 5% chance. Therefore, an investigator merely states that if less than 5 % of the distribution area created by these chance values is encompassed by this test statistic then 95%

certainty is attained. If the statistic derived from the analysis falls in a region of the chance values that is 5% or smaller, then the null hypothesis is rejected with at least 95% confidence. The region within which the derived test statistic falls is called the p-value. The results in the appendices of this study have the p-value listed.

Step 5. Make a decision.

Compare the probability value to .05. If the value is less than .05, reject the null and accept the alternate hypothesis. If the value is greater than .05, fail to reject the null hypothesis.

F-6. *Chi-square (χ^2) Analysis for hypothesis testing.*

(Used in Appendix H, Appendix I, Appendix N).

The chi-square analysis is used for experimental designs which compare the proportion distribution between two or more populations. The proportions of each population are organized into rows and columns. The chi-square analysis will detect evidence that contradicts a null (no effect) hypothesis (H_0). If evidence is found which contradicts the null hypothesis, the null is rejected and the alternative hypothesis (H_1) is accepted. The null hypothesis is that proportions of each of the rows in the columns are equal. The χ^2 statistic is defined as:

$$\chi^2 = \Sigma \left[\frac{(f_o - F_e)^2}{F_e} \right]$$

where F_e is the expected frequency in a cell of the table

and f_o is the observed frequency in a cell.

The χ^2 value derived in the analysis is a relative indication of the discrepancy between the observed and the expected. The larger χ^2, the more likely the proportion distributions are not equal. The number of rows (k) is taken into consideration when determining if the derived χ^2 is within the desired level of certainty. These analyses were run on the BMDP program 4F.

F-7. *Correlation Coefficient (r)*

The correlation coefficient, *r*, expresses the strength and the direction of the linear relationship between independent variable, *x*, and dependent variable, *y*. This value does not imply causation, merely how related x and y are.

$$r = \frac{n(\Sigma xy) - (\Sigma x)(\Sigma y)}{\sqrt{[n(\Sigma x^2) - (\Sigma x)^2][n(\Sigma y^2) - (\Sigma y)^2]}}$$

where *n* is the number of paired observations, *x* is a random variable, and *y* is a random variable.

Strength: The correlation coefficient, *r*, is always expressed between the values of -1 and 1. The further a value is from zero, the stronger the relationship between *x* and *y*. If no relationship exists between variables, $r = 0$. No relationship between the two implies that a change in y can not be related to a change in x.

Direction: If the correlation coefficient is positive, a positive change in *x* corresponds to a positive change in *y* and a negative change in *x* corresponds to a negative change in *y*. If the coefficient is negative a positive change in *x* corresponds to a negative change in *y* and a negative change in *x* corresponds to a positive change in *y*.

This analysis was run using the BMDP program 6R.

F-8. *Multiple Regression and the Coefficient of Multiple Determination (R^2).*

(Used in Appendix P, Appendix Q).

Regression is used to determine the best-fit line between a plot of the dependent variables. The regression derives the variable R^2, the coefficient of multiple determination, which is used in hypothesis testing.

The regression can be structured to find evidence that contradicts the null hypothesis. The null hypothesis is stated: the independent variables contribute to 0% of the variability of the dependent variable (H_0: $R^2 = 0$). The alternate hypothesis is stated: the independent variables contribute to more than 0% of the variability (H_1: $R^2 > 0$).

The following description explains how R^2 is derived and why it is of interest.

If a line is drawn between the points on a plot, not all of the points will lie on the line. The vertical distance from the drawn line and the actual data points can be measured. These measurements are called residuals. The multiple regression analysis determines what the best fitting line between the points is by minimizing the sum of squares of the residuals.

The predicted line can be represented by the equation: $Y' = a + b_1x_1 + b_2x_2$,

and the actual data points can be represented by Y.

It is possible to calculate the difference between the observed and the predicted values by the equation $Y - Y'$.

When observed values differ from the predicted values, most of the variation can not be explained. The unexplained variation is calculated by the formula: Σ (Y-Y').

But, this unexplained variation in the dependent variable is not the total variation. The total variation is calculated by: $\Sigma (Y-\overline{Y})$.

An equation then exists for the explained variation (that related to the independent variables in the equation): Explained variation = Total variation - Unexplained variation.

The coefficient of multiple determination, R^2, measures the percent of the total variation in the dependent variable, Y, that is explained by the set of independent variables.

It can be written:

$$R^2 = \frac{\text{(Total variation - Unexplained variation)}}{\text{Total variation}}$$

Thus, it is possible to determine if a set of variables accounts for the variability in the dependent variable, Y.

F-9. *Analysis of Variance (ANOVA) and F-statistic.*

Used in Appendices G, J, K, L, M, O and R.

Analysis of variance is used to test if the mean of a dependent variable changed caused by an independent variable. The null hypothesis is that two means of independent categories are equal $(H_0 : \overline{y}_1 = \overline{y}_2)$. The alternate hypothesis is that the two means are not equal

$(H_0: \overline{y}_1 \neq \overline{y}_2)$. In the ANOVA these hypotheses are tested with the distribution of the F-statistic. The steps below describe how the F-statistic is derived.

The first step in the analysis of variance is to organize the observed values into cells of a table according to the independent variables. Once this is done, variability between cells (categories) can be measured and variability within each cell (category) can be measured.

F is the ratio of these two types of variances:

$$F = \frac{\text{between-category variance}}{\text{within-category variance}}.$$

The reasoning is that if the total variance between the categories is larger than the total variance within the categories, the sources of the two types of variance are different, in which case the independent variables are most likely responsible for the variability between the cells. Therefore, as F grows larger, it becomes more likely that the null hypothesis will be rejected. This is described in greater detail below.

These variances can best be understood if they are observed in a table.

Category of Air Conditioner Use	# of Households in each Category (n)	Household Response to Noise (y_{ij})	Category Mean $\overline{Y}_i = \frac{\Sigma y_j}{n_i}$	Within Category Variability $\sum_{j=i}^{n_i} (Y_{ij} - \overline{Y}_i)^2$
None ($i = 1$)	30	0,1,0,1,0,3,5, 4,...... $\frac{\Sigma y_j}{n_i}$	$\sum_{j=i}^{n_i} (Y_{ij} - \overline{Y}_i)^2$ $\frac{\Sigma y_j}{n_i}$	$\sum_{j=i}^{n_i} (Y_{ij} - \overline{Y}_i)^2$
Some ($i = 2$)	30	0,1,4,3,2,0,2, 1,.....	$\frac{\Sigma y_j}{n_i}$	$\sum_{j=i}^{n_i} (Y_{ij} - \overline{Y}_i)^2$
Continuously ($i = 3$)	30	1,0,4,3,5,2,1, 2,...	$\frac{\Sigma y_j}{n_i}$	$\sum_{j=i}^{n_i} (Y_{ij} - \overline{Y}_i)^2$

Total Within Category Variability = $\Sigma \left(\sum_{j=i}^{n_i} (Y_{ij} - \overline{Y}_i)^2 \right)$

Total Between Category Variability = $\sum_{i=1}^{k} n_i (\overline{Y}_i - \overline{Y})^2$

Where: n = number of participants in category,

N = number of participants in experiment,

Y_{ij} = observation within a category,

$\overline{Y}_i$ = mean of a category,

$\overline{Y}$ = grand mean of the experiment,

i = category, and

j = participant in that category.

K = number of categories.

Source of variation	Degrees of Freedom	Mean Square
Between Category	$k - 1$	$\frac{\text{Between Category Variation}}{(k-1)} = \text{Mean B.C.V.}$
Within Category	$N - k$	$\frac{\text{Within Category Variation}}{(N-k)} = \text{Mean W.C.V.}$

The F-statistic is then calculated as $\frac{\text{MeanBCV}}{\text{MeanWCV}}$.

This F-statistic is tested against a critical value, based on the degrees of freedom of the experiment and the level of certainty the investigator chooses. The larger the F-value, the more confidently the null hypothesis can be rejected.

Appendix G: Hypothesis Test for Priming effects; is the annoyance with overall noise inflated?

H_0 : A-during group and B-during group have the same average level of annoyance with overall noise.

H_1 : A-during group and B-during group have different average levels of annoyance with overall noise.

Analysis: analysis of variance (Appendix F-9).

Independent Variable: Interview Group with the levels: A-During group; B-During group.

Dependent Variable: Average annoyance level with overall noise (responses to question 4b).

Results: $F(1, 57) = 0.27$; $p = 0.6038$;

Decision: $p > .05$; therefore fail to reject H_0.

Conclusion: Fail to detect different annoyance levels with overall noise between A-during group and B-during group. There is no evidence for exaggerated annoyance levels in A-during.

Hypothesis Test for Priming effects; is the annoyance with car noise inflated?

H_0 : A-during group and B-during group have the same average level of annoyance with car noise.

H_1 : A-during group and B-during group have different average levels of annoyance with car noise.

Analysis: analysis of variance (Appendix F-9).

Independent Variable: Interview Group with the levels: A-During group; B-During group.

Dependent Variable: Annoyance level with cars (responses to question 9b).

Results: F(1, 73), 2.72), p = 0.1031

Decision: p > .05; therefore fail to reject H_0.

Conclusion: Fail to detect different annoyance levels with car noise between A-during group and B-during group. There is no evidence for exaggerated annoyance levels in A-during.

Hypothesis Test for Priming effects; is annoyance with fixed-wing aircraft noise inflated?

$\mathbf{H_0}$ **:** A-during group and B-during group have the same average level of annoyance with fixed-wing aircraft noise.

$\mathbf{H_1}$ **:** A-during group and B-during group have different average levels of annoyance with fixed-wing aircraft noise.

Analysis: analysis of variance (Appendix F-9).

Independent Variable: Interview Group with the levels: A-During group; B-During group.

Dependent Variable: Annoyance level with fixed-wing aircraft (responses to question 9b).

Results: F(1, 119) = 0.02; p = 0.8870

Decision: p > .05; therefore fail to reject H_0.

Conclusion: Fail to detect different annoyance levels with fixed-wing aircraft noise between A-during group and B-during group. There is no evidence for exaggerated annoyance levels in A-during.

Hypothesis Test for Priming effects; is annoyance with helicopter noise inflated?

$\mathbf{H_0}$ **:** A-during group and B-during group have the same average level of annoyance with helicopter noise.

$\mathbf{H_1}$ **:** A-during group and B-during group have different average levels of annoyance with helicopter noise.

Analysis: analysis of variance (Appendix F-9).

Independent Variable: Interview Group with the levels: A-During group; B-During group.

Dependent Variable: Average annoyance level with helicopters (responses to question 9b).

Results: $F(1, 125) = 1.69$; $p = 0.1959$

Decision: $p > .05$; therefore fail to reject H_0.

Conclusion: Fail to detect different annoyance levels with helicopter noise between A-during group and B-during group. There is no evidence for priming exaggerated annoyance levels.

Appendix H

Hypothesis test to determine if residents noticed a change in the noise level in the neighborhood. Did the percentage of "yes" responses change for the question: "Have you noticed any changes in the noise level in your neighborhood?"

H_0 : A-Pre group and B-During group have the same percentage of "Yes" responses to the question.

H_1 : B-During group has a greater percentage of "Yes" responses to the question than the A-pre group.

Analysis: Chi-square analysis (Appendix F-6).

Independent Variable: A-Pre group; B-During group.

Dependent Variable: Percentage of yes and no responses to question 5:

Cell proportions:

Table 4.1.1. Responses to the question:
"Have you noticed any changes in the noise level in your neighborhood?"

	Pre-Olympic Games Group A	During-Olympic Games Group B	Total Residents
Yes, noticed change.	19	48	67
No, didn't notice.	51	24	75
Total Residents	70	72	142 residents

Results: chi-square = 22.25, $p < 0.0001$.

Decision: $p < .05$; therefore, reject H_0 and accept H_1.

Conclusion: A-Pre group and B-during group did not have the same percentage of yes responses. B-during group had a greater percentage.

Appendix I

Hypothesis test to determine if more residents became annoyed with noise during the Olympcs. Did the percentage of yes and no responses change for the question: "Does the level of noise in the neighborhood bother you?"

H_0 : A-Pre group and B-During group have the same percentage of "Yes" responses to the question.

H_1 : B-During group has a greater percentage of "Yes" responses to the question than A-Pre group.

Analysis: Chi-square analysis (Appendix F-6).
Independent Variable: A-Pre group; B-During group.
Dependent Variable: Percentage of yes and no responses to question 4a.

Cell proportions:

Table 4.2.2 Responses to the question: "Does the level of noise in the neighborhood bother you?"

	Pre-Olympic Games Group A	During-Olympic Games Group B	Total Residents
Yes, am annoyed	25	27	52
Not, am not annoyed	45	45	90
Total residents	70	72	142 residents

Results: chi-square =0.049; p = 0.8252.

Decision: $p > .05$; therefore fail to reject H_0.

Conclusion: Fail to detect a difference in the proportion of "Yes" responses between the A-Pre group and the B-during group.

Appendix J

Hypothesis Test to determine if residents became more annoyed with fixed-wing aircraft noise during the Olympics.

H_0 : The community's average level of annoyance was the same before the Olympics as it was during the Olympics.

H_1 : The community's average level of annoyance was lower before the Olympics than it was during the Olympics.

Analysis: analysis of variance (Appendix F-9).

Independent Variable: A-Pre group; B-During group

Dependent Variable: Average annoyance level with fixed-wing aircraft noise (responses to question 9b).

Results: $F(1,131) = 0.52$, $p = 0.4713$.

Cell means:

A-Pre	B-During
1.045	**.879**

0 means not at all annoyed;

1 means slightly annoyed;

2 means moderately annoyed;

3 means very much annoyed;

4 means extremely annoyed.

Decision: $p > .05$; therefore fail to reject H_0.

Conclusion: Fail to detect different annoyance levels with fixed-wing aircraft noise between A-Pre group and B-During group.

Appendix K

Hypothesis Test to determine if residents became more annoyed with helicopter noise during the Olmpics.

H_0 : The community's average level of annoyance was the same before the Olympics as it was during the Olympics.

H_1 : The community's average level of annoyance was lower before the Olympics than it was during the Olympics.

Analysis: analysis of variance (Appendix F-9).

Independent Variable: A-Pre group; B-During group

Dependent Variable: Average annoyance level with helicopter noise (Responses to question 9b).

Results: $F(1,129) = 0.11$, $p = 0.7385$.

Cell means:

A-Pre	B-During
1.274	**1.188**

0 means not at all annoyed;

1 means slightly annoyed;

2 means moderately annoyed;

3 means very much annoyed;

4 means extremely annoyed.

Decision: $p > .05$; therefore fail to reject H_0.

Conclusion: Fail to detect different annoyance levels with helicopter noise between A-Pre group and B-During group.

Appendix L

Hypothesis Test to determne if residents within the higher DNLs have higher levels of annoyance. This is only for the DNL categories measured during the Olympics.

H_0 : Residents interviewed during the Olympics have the same average level of annoyance with overall noise regardless of DNL.

H_1 : Residents interviewed during the Olympics have different average levels of annoyance with overall noise depending on if the DNL surrounding their home.

Analysis: analysis of variance (Appendix F-9).

Independent Variable: DNL category with the levels: 61, 62, 63, 64, 66, 70, or 72.

Dependent Variable: Average annoyance level with overall noise (Responses to question 4b).

Results: $F(6, 125) = 1.80$; $p = 0.1035$.

Cell means:

	61 DNL	62 DNL	63 DNL	64 DNL	66 DNL	70 DNL	72 DNL
annoyance	1.05	.57	1.18	1.56	1.33	1.40	0.00

0 means not at all annoyed;

1 means slightly annoyed;

2 means moderately annoyed;

3 means very much annoyed;

4 means extremely annoyed.

Decision: $p > .05$; therefore fail to reject H_0.

Conclusion: Fail to detect different average levels of annoyance with overall noise due to DNL surrounding home.

Appendix M

Hypothesis Test to determine if those residents that experienced a greater change in DNL have higher annoyance levels with overall noise.

H_0 : Residents interviewed during the Olympics all have the same average level of annoyance with overall noise regardless of amount of change in DNL.

H_1 : Residents interviewed during the Olympics have different average levels of annoyance with overall noise depending on the change in DNL surrounding their home changed more.

Analysis: analysis of variance (Appendix F-9).

Independent Variable: "change in DNL" category with the levels: 0 (no change), 3, 4, 5, 6, 7, 8, 10 dBA.

Dependent Variable: Average annoyance level with overall noise (responses to question 4b).

Results: $F(7, 124) = 1.25$; $p = 0.2798$.

Decision: $p > .05$; therefore fail to reject H_0.

Conclusion: Fail to detect any difference in the average level of annoyance with overall noise regardless of the change in DNL surrounding residents' homes.

Hypothesis Test to determine if those residents that experienced a greater change in DNL have higher annoyance levels with helicopter noise.

H_0 : Residents interviewed during the Olympics all have the same average level of annoyance with helicopter noise regardless of amount of change in DNL.

H_1 : Residents interviewed during the Olympics have different average levels of annoyance with helicopter noise depending on the change in DNL surrounding their home changed more.

Analysis: analysis of variance (Appendix F-9).

Independent Variable: "change in DNL" category with the levels: 0 (no change), 3, 4, 5, 6, 7, 8, 10 dBA.

Dependent Variable: Average annoyance level with helicopter noise (Responses to question 9b).

Results: $F(7, 119) = 1.23$; $p = 0.2903$.

Decision: $p > .05$; therefore fail to reject H_0.

Conclusion: Fail to detect a difference between the average level of annoyance with helicopter noise regardless of the change in DNL surrounding their home.

Appendix N

Hypothesis test to determine if the percentages of people highly annoyed in this study are the same as the percentage predicted by the Schultz curve.

H_0 : The observed percentages of highly annoyed at each DNL are the same as those predicted by Schultz.

H_1 : The observed percentages of highly annoyed at each DNL are different from those predicted by Schultz.

Statistical Analysis: 15 different Chi-square analyses (Appendix F-6).
Dependent Variable: The dependent variable is *percent highly annoyed* with overall noise (responses to question 4b) (see Appendix F-3 for calculation of *percent highly annoyed*).
The data: The observed data is compared to the predicted data of the Schultz curve. Because the observed percentages varied greatly between DNL categories in this study, a best-fittng line was derived from the same regression procedure as that applied to the Schultz data. It makes sense to compare best-fitting values of observed data to Schultz's best-fitting values. This strengthened the meaning behind the conclusion from this analysis. Otherwise, non-systematic differences would have resulted, makng interpretation difficult.
Results: See table below.

	DNL 56	DNL 61	DNL 62	DNL 63	DNL 64
Overall Noise	Chi-sq = 0.618	Chi-sq = 0.213	Chi-sq = 15.584*	Chi-sq = 17.475*	Chi-sq = 40.535*
Fixed-wing aircraft Noise	Chi-sq = 0.529	Chi-sq = 0.000	Chi-sq = 0.000	Chi-sq = 0.000	Chi-sq = 0.000
Helicopter Noise	Chi-sq = 60.657*	Chi-sq = 34.217*	Chi-sq = 36.561*	Chi-sq = 42.890*	Chi-sq = 46.771*

***Decision:** This analysis did not include the calculation of a probability value. Instead, the chi-square derived in this analysis was compared to a statistical table for a .05 probability value. The table is used by referring to the cell with the appropiate degrees of freedom, in this case one degree on freedom. The table indicated the results should be compared against a critical value of 3.84, which is the determining value for analyses with one degree of freedom at a 0.05 probability level (95% certainty). In the cases that the obtained chi-square value is greater than 3.84, the observed population proportions and those predicted by the Schultz curve are different.

Conclusion: A report of the categories in which the Schultz curve did not predict the percentage of people highly annoyed near a general aviation airport is in the table below.

	DNL 56	DNL 61	DNL 62	DNL 63	DNL 64
Overall Noise			Different from Schultz.	Different from Schultz.	Different from Schultz.
Fixed-Wing Aircraft Noise					
Helicopter Noise	Different from Schultz.	Different from Schultz.	Different from Schultz.	Different from Schultz.	Different from Schultz.

Appendix O

Hypothesis Test to determine if residents are more annoyed with fixed-wing aircraft noise or with helicopter noise.

Prior to the Olympics

$\mathbf{H_0}$: Each resident has the same average level of annoyance with fixed-wing aircraft noise and helicopter noise.

$\mathbf{H_1}$: Each resident has different average levels of annoyance with fixed-wing aircraft noise and helicopter noise.

Analysis: analysis of variance (Appendix F-9).

Independent Variables: 1)Pre-period; During-period 2) fixed-wing aircraft, helicopter.

Dependent Variable: Annoyance level with each source (responses to question and 9b).

Results: $F(1, 59) = 4.84$; $p = 0.0318$.

Cell means:

Fixed-Wing Noise Annoyance	Helicopter Noise Annoyance
.95	1.28

0 means not at all annoyed;

1 means slightly annoyed;

2 means moderately annoyed;

3 means very much annoyed;

4 means extremely annoyed.

Decision: $p < .05$; therefore reject H_0 and accept H_1.

Conclusion: Because the average level of annoyance is highest for the helicopters, the conclusion is that the level of annoyance with helicopters is significantly higher than the levels of annoyance with fixed-wing aircraft.

Hypothesis Test to determine if residents are more annoyed with fixed-wing aircraft noise or with helicopter noise.

During the Olympics

H_0 : Each resident has the same average level of annoyance with fixed-wing aircraft noise and helicopter noise.

H_1 : Each resident has differing average levels of annoyance with fixed-wing aircraft noise and helicopter noise.

Analysis: analysis of variance (Appendix F-9).

Independent Variables: 1)Pre-period; During-period 2) overall, fixed-wing aircraft, helicopter.

Dependent Variable: Annoyance level with each source (responses to questions 9b).

Results: $F(1, 117) = 1.90$; $p = 0.0001$.

Fixed-Wing Noise Annoyance	Helicopter Noise Annoyance
.92	1.45

0 means not at all annoyed;

1 means slightly annoyed;

2 means moderately annoyed;

3 means very much annoyed;

4 means extremely annoyed.

Decision: $p < .05$; therefore reject H_0.

Conclusion: Because the average level of annoyance with the helicopters is highest, the conclusion is that the level of annoyance with helicopters is significantly higher than the levels of annoyance with fixed-wing aircraft noise.

Appendix P

Hypothesis test to determine if the variables DNL, duration of residence, annoyance with fixed-wing aircraft noise, annoyance with car noise and annoyance with helicopter noise have meaningful relationships to annoyance with overall noise.

H_0 : These five variables contribute nothing to the variability in annoyance levels with overall noise.

H_1 : These five variables do contribute to the variability in annoyance levels with overall noise.

Analysis: Multiple Regression (Appendix F-8).

Independent Variables: DNL, duration of residence, annoyance with fixed-wing aircraft noise, annoyance with car noise and annoyance with helicopter noise.

Dependent Variable: Annoyance level with overall noise (responses to question 4b).

Results: $R^2 = 0.4447$, $p = 0.0005$.

Decision: $p < .05$; therefore, reject H_0 and accept H_1.

Conclusion: The regression on the Pre-Olympic data included five independent variables which conclusively accounted for 44.5% of the variance. This means that the overall annoyance changes as these variables change. The correlations listed in the text in Table 4.1.1 indicate the strength and the direction of the relationship between each of the independent variables and the dependent variable.

Appendix Q

Hypothesis test that the variables DNL, change in DNL, duration of residence, annoyance with fixed-wing aircraft noise, annoyance with car noise and annoyance with helicopter noise have meaningful relationships to annoyance with overall noise.

H_0: These five variables contribute nothing to the variability in annoyance levels with overall noise.

H_1: These five variables do contribute to the variability in annoyance levels with overall noise.

Analysis: Regression (Appendix F-8).

Independent Variables: DNL, change in DNL, duration of residence, annoyance with fixed-wing aircraft noise, annoyance with car noise and annoyance with helicopter noise.

Dependent Variable: Annoyance level with overall noise.

Results: $R^2 = 0.3417$, $p = 0.0381$.

Decision: $p < .05$; therefore, reject H_0 and accept H_1.

Conclusion: The regression on the During-Olympic data included five independent variables which conclusively accounted for 34.7% of the variance. This means that the overall annoyance changes as these variables change. The correlations listed in the text in Table 4.1.2 indicate the

strength and the direction of the relationship between each of the independent variables and the dependent variable.

Appendix R

Hypothesis test to determne if people with higher DNLs surrounding their home are more annoyed by helicopter noise.

Prior to the Olympics

H_0 : Residents of the A-Pre groups all have the same average level of annoyance with helicopter noise regardless of DNL.

H_1 : Residents of the A-Pre groups have different average levels of annoyance with helicopter noise depending on the DNL surrounding their home.

Analysis: analysis of variance (Appendix F-9).

Independent Variable: DNL category with the levels: 54, 55, 56, 57, 58, 59, 60, 61, 62, 63.

Dependent Variable: Annoyance level with helicopter noise (responses to question 9b).

Results: $F(8, 53) = 1.62$; $p = 0.1410$.

Decision: $p > .05$; therefore fail to reject H_0 and accept H_1.

Conclusion: Residents interviewed during the Olympics do not have different average levels of annoyance with helicopter noise due to the DNL surrounding their home.

During the Olympics

$\mathbf{H_0}$ **:** Residents of the A and B-during groups all have the same average level of annoyance with helicopter noise regardless of DNL.

$\mathbf{H_1}$ **:** Residents of the A and B-during groups have higher average levels of annoyance with helicopter noise if the DNL surrounding their home is higher.

Analysis: analysis of variance (Appendix F-9).

Independent Variable: DNL category with the levels: 61, 62, 63, 64, 66, 70, or 72.

Dependent Variable: Annoyance level with overall noise (responses to question 4b).

Results: $F(6, 120) = 2.52$; $p = 0.0245$.

Cell means:

DNL	61	62	63	64	66	70	72
Annoyance level	1.667	.892	1.296	3.000	1.667	2.400	.000

Decision: $p < .05$; therefore, reject H_0.

Conclusion: Residents interviewed during the Olympics have different average levels of annoyance with helicopter noise due to the DNL surrounding their home. However, these average levels do not increase or decrese with DNL in a systematic manner (see Figure 4.4.2).